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TECHNICAL REPORT
70-39-ES

A COMPARISON OF ANNUAL RAINFALL PROBABILITIES IN THAILAND AND THE CANAL ZONE VICINITY

by

Ruth L. Wexler

March 1970

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13. ABSTRACT

Annual rainfall probabilities are compared among stations in the Canal Zone and Thailand. A variety of probability maps and charts are provided. Universal descriptors of annual rainfall regimes are sought in statistical parameters. Despite the total amount of rainfall at any one point, fairly extensive areas are often subject to approximately the same degree of relative variation of annual rainfall. Consequently, the set of the mean and the coefficient of variation is used to characterize annual rainfall. This set of statistics yields reasonably reliable predictions for design or long-range planning. On the whole, the rainfall of the Canal Zone is somewhat heavier and less variable than that of Thailand.

In addition to the overall comparisons of rainfall regimes, specific aspects of annual rainfall distributions are analyzed. Examples of the areal distribution of extreme annual rainfall are shown for selected years. The relationship between annual rainfall and runoff is briefly discussed, as well as the relationship between annual and monthly rainfall distributions. Limited observations indicate that it is possible in some cases to anticipate an unusually wet year from monthly trends early in the rainy season. Stations with analogous annual rainfall regimes do not necessarily have analogous monthly rianfall regimes unless the durations of the rainy seasons are the same. Coincidences in the occurrence of extreme conditions in Thailand and the Canal Zone are noted. Extensive stress in any one area often reflects marked disturbances in global weather patterns. Such information is of interest in the scheduling of testing operations.

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	ROLE	WT	ROLE	WT	ROLE	WT
Probability	8					
Parameters	8, 4					
Rainfall	9		9			
Thailand	9		9			
Canal Zone	9		9			
Area			0			
Distribution (properly)			8			
Duration			8			

ERRATA
TECHNICAL REPORT 70-39-ES

Page 3	Figure 1b	Insert is located at top of map.
Page 4	Figure 2	substitute CHANTHABURI 1931-60 for CANTHABURI.
Page 5	Footnote	After equation add: (4) p. 47.
Page 7	Figure 3b	the 125 cm isohyet of mean annual rainfall is missing around Stations 351, 378, and 379.
Page 12		for $A \approx 0.8$ S** substitute $D \approx 0.8$ S** and where A = mean deviation substitute D = mean deviation and footnote** after theoretically substitute D for A in A = .7979 S (33); and change (4) to (3) after Table IVa (Appendix)
Page 23	Figure 6b	Add >95 in the space to the left of station 552.
Page 53	Table VIII	After Cristobal add $\leq$ before 20 and $\geq$ 80; after Chanthaburi add $\leq$ before 20 and $\geq$ before 80.

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FOREWORD

In previous reports of the Earth Sciences Laboratory, various aspects of the climate of selected stations in humid tropical locations have been compared with those at test sites near Balboa Heights and Cristobal in the Canal Zone. Climatic analogies depended on monthly or annual climatic means (normals). Such investigations have been helpful in scheduling and evaluating tests of materiel intended for use in tropical environments. The task is carried on here by the application of statistical techniques. In this pilot study annual rainfall probabilities are compared among stations in the Canal Zone and Thailand. Universal descriptors of annual rainfall are sought in statistical parameters, which aid not only in ascertaining analogous regimes, but in predicting annual rainfall. The results provide quantitative information for testing, design, and long-range planning.

This study was authorized under project PROVOST, and performed under 1T062112A129, Environmental Research, Task 03, Methods for Predicting Environmental Conditions. Work in this field is directed toward the development of realistic estimates of natural environments in any season or location throughout the world.

The Cartography in this report was compiled by Miss Olive Lesueur, under the supervision of Mr. Aubrey Greenwald, Chief of the Cartography Office, Earth Sciences Laboratory.

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ABSTRACT

Annual rainfall probabilities are compared among stations in the Canal Zone and Thailand. A variety of probability maps and charts are provided. Universal descriptors of annual rainfall regimes are sought in statistical parameters. Despite the total amount of rainfall at any one point, fairly extensive areas are often subject to approximately the same degree of relative variation of annual rainfall. Consequently, the set of the mean and the coefficient of variation is used to characterize annual rainfall. This set of statistics yields reasonably reliable predictions for design or long-range planning. On the whole, the rainfall of the Canal Zone is somewhat heavier and less variable than that of Thailand.

In addition to the overall comparisons of rainfall regimes, specific aspects of annual rainfall distributions are analyzed. Examples of the areal distribution of extreme annual rainfall are shown for selected years. The relationship between annual rainfall and runoff is briefly discussed, as well as the relationship between annual and monthly rainfall distributions. Limited observations indicate that it is possible in some cases to anticipate an unusually wet year from monthly trends early in the rainy season. Stations with analogous annual rainfall regimes do not necessarily have analogous monthly rainfall regimes unless the durations of the rainy seasons are the same. Coincidences in the occurrence of extreme conditions in Thailand and the Canal Zone are noted. Extensive stress in any one area often reflects marked disturbances in global weather patterns. Such information is of interest in the scheduling of testing operations.

A COMPARISON OF ANNUAL RAINFALL PROBABILITIES IN THAILAND AND THE CANAL ZONE VICINITY

1. Introduction

1.1 Background and scope

Climatic analog investigations have been carried out for many parts of the world, including Southeast Asia (1). In these studies a variety of climatic factors were assessed in order to determine the extent to which world-wide conditions are represented by the test sites in the Canal Zone. Analogies were based mainly on long-term monthly or annual climatic means (normals). The objective here is to provide more quantitative information than that found in the earlier analog studies, both to increase efficiency in planning specific tests and to develop realistic design criteria for tropical environments.

In this pilot study, annual rainfall probabilities are compared among stations in the Canal Zone and Thailand. Rainfall regimes are described by statistical parameters. Prediction charts and nomograms are supplied. Tables I and II give the station details for the Canal Zone (2-4) and Thailand (3), respectively. Wherever possible, a network of stations in the Canal Zone and vicinity* are used rather than just the test sites of Balboa Heights and Cristobal, as has been the custom (1). Figure 1a is a station location map for the Canal Zone, while Figure 1b is a station location map for Thailand, with an insec for the Canal Zone to show the difference in size between the two regions. The main physiographic provinces (5) of Thailand are labelled in Figure 1b.

1.2 Procedure

Annual rainfall distributions are analyzed by both empirical and theoretical methods. Overall comparisons of selected stations in the Canal Zone and Thailand are made first by a set of cumulative percent probability plots (Figure 2). These plots were based on 30-year records, since longer records were not available in all cases. The "representativeness" of 30-year records has been discussed (6-8) and is considered later. Universal descriptors of the rainfall regimes are then sought in statistical parameters, which are examined for stability with time. Temperature regimes

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* "and vicinity" is understood throughout the report when areas are discussed.

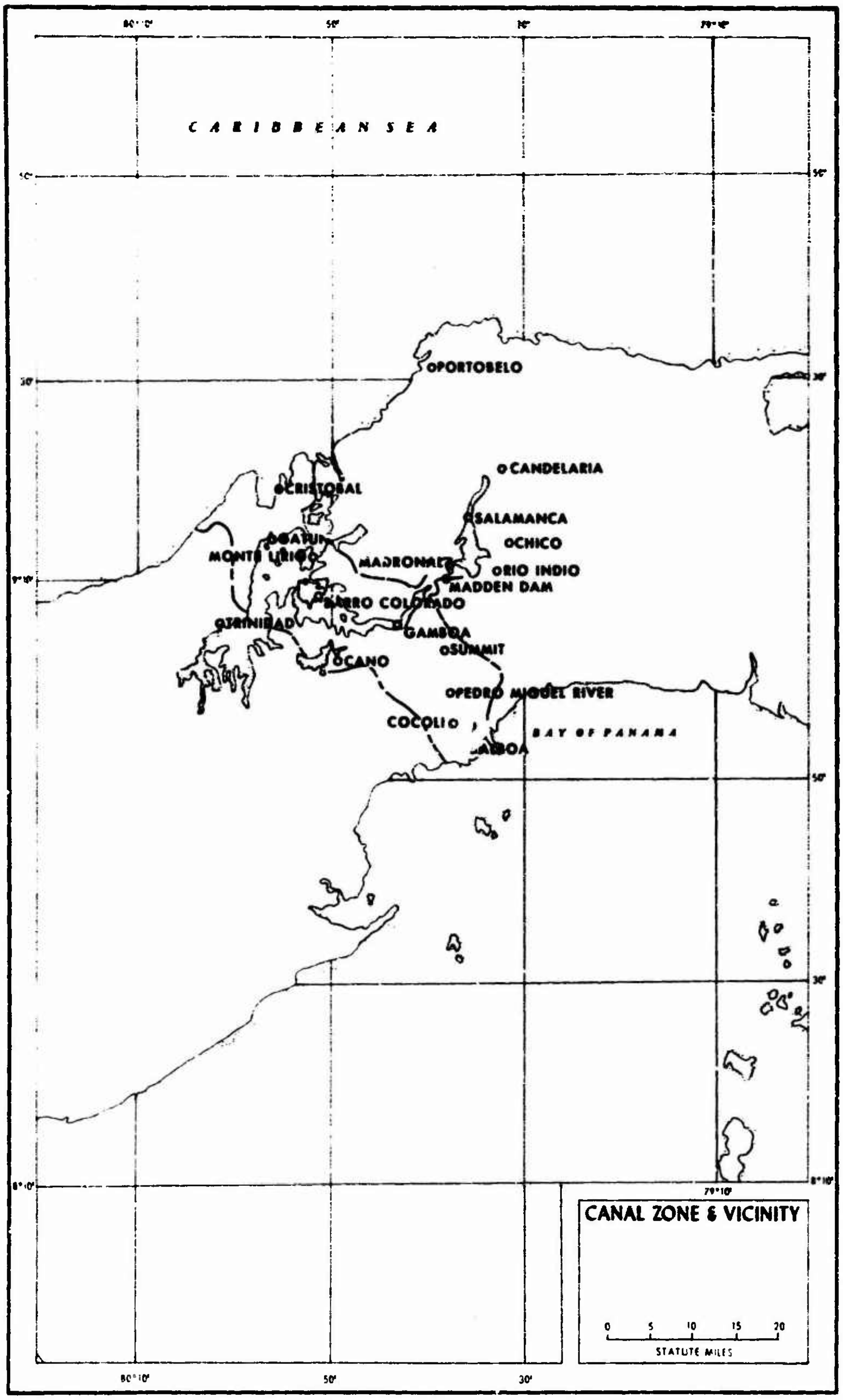

Figure 1a: Canal Zone and vicinity.

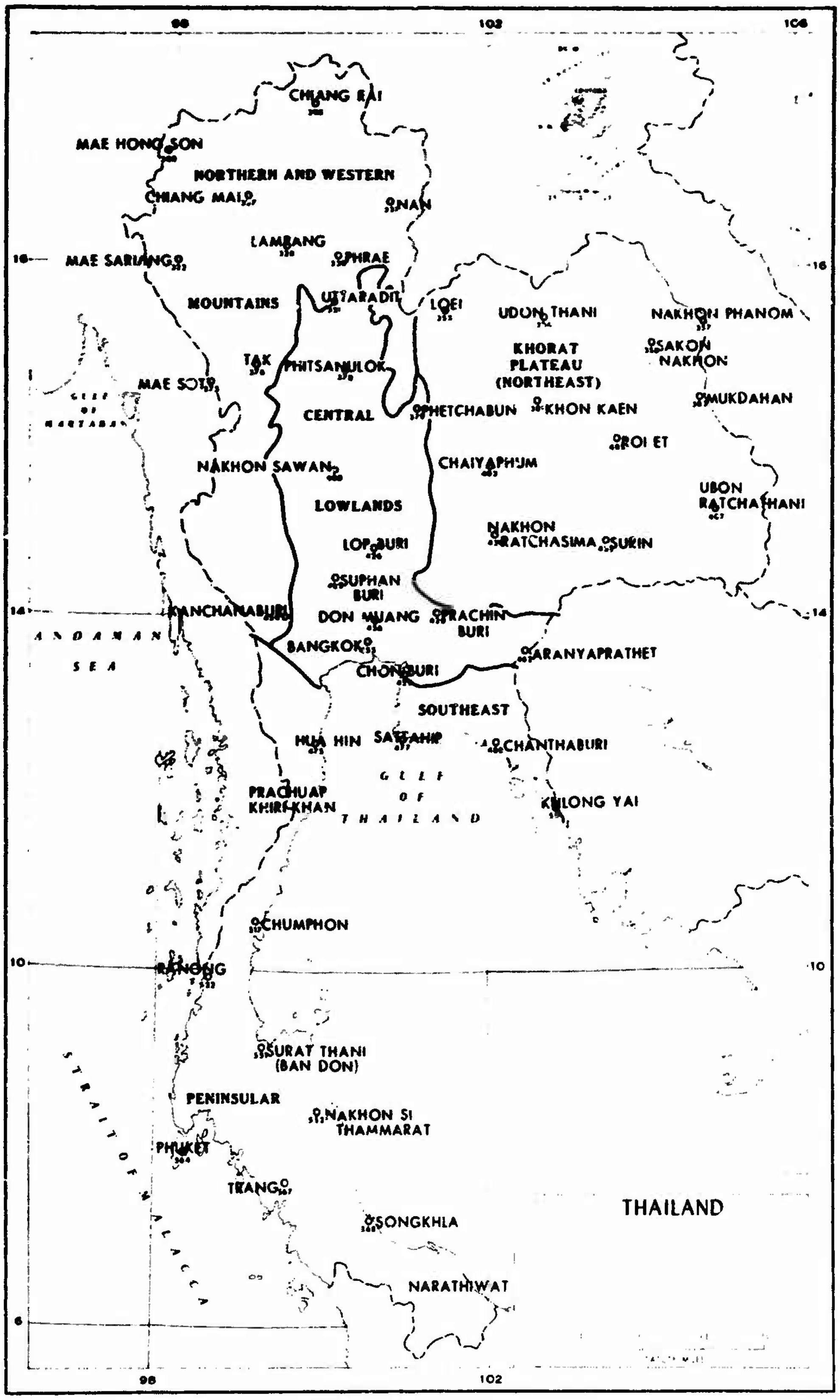

Figure 1b: Thailand (with inset for Canal Zone).

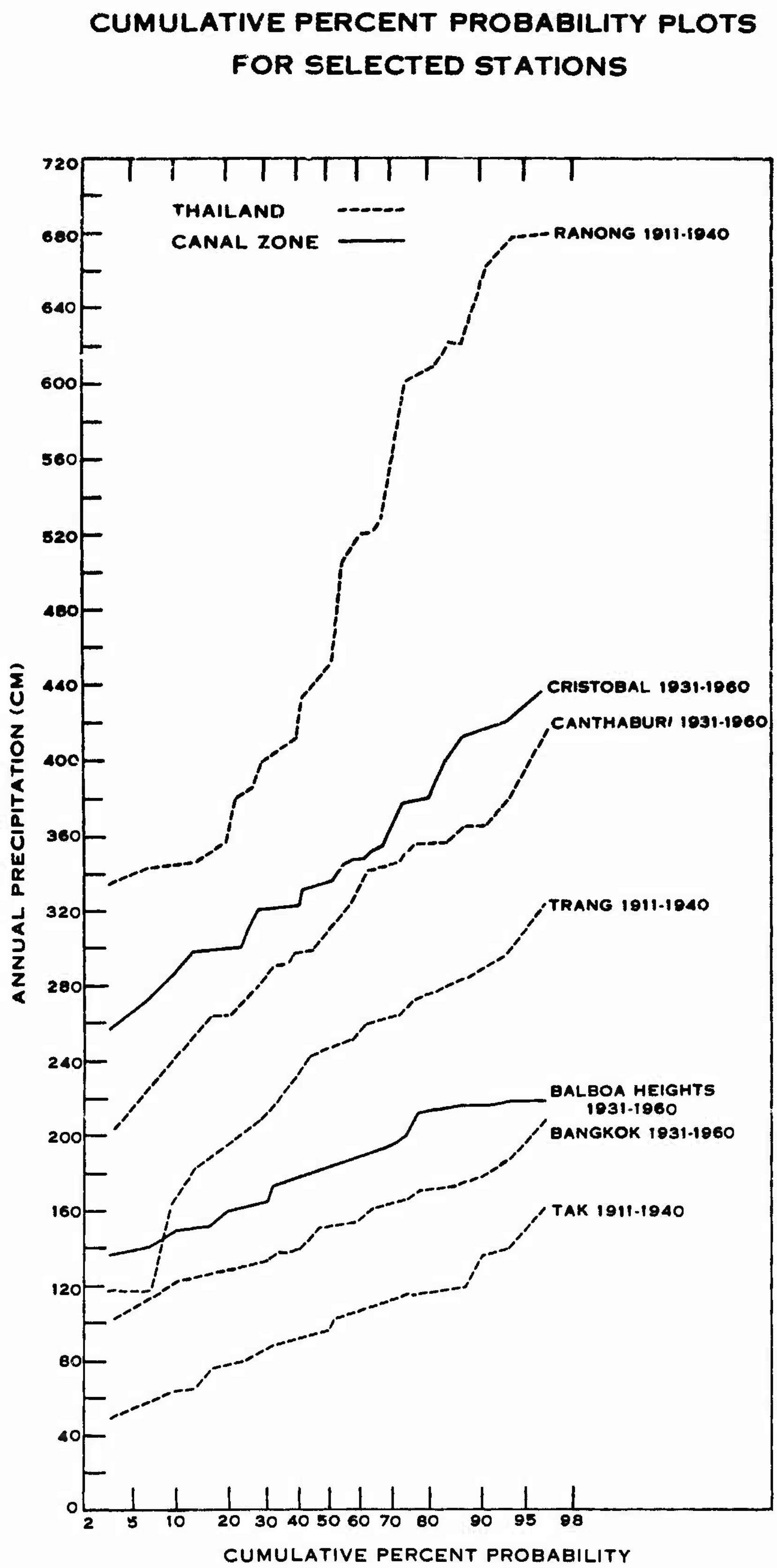

Figure 2: Cumulative percent probability plots of annual rainfall for selected stations.

have been classified by standard deviation and excess (9) Since the annual rainfall for Thailand appears to follow the normal Gaussian distribution (Figure 2), as has been found for the Canal Zone (4) and elsewhere (10, 11), only the mean and the standard deviation are required for routine prediction purposes (12). Maps of these parameters have been presented elsewhere for estimating extreme temperature probabilities for the warmest and coldest months (13). Figures 3a and 3b are maps with similar parameters, except that the standard deviation is expressed as a percent of the mean, that is, as the coefficient of variation*. The information in Figure 3a (Canal Zone) was derived from sets of the mean and the standard deviation of annual rainfall computed previously (4). Maps of the coefficient of variation, particularly useful for agricultural planning, have been prepared by other investigators for various countries (10, 11).

The combination of the mean and the coefficient of variation of annual rainfall constitutes the principal basis of analogy for annual rainfall regimes in this study. Reasons for this choice of criteria are enumerated. Stations in Thailand most closely analogous to either of the Canal Zone test sites are listed in Section 5; limits of analogy are indicated. Similar limits are applicable to Figures 3a and 3b for analogous areas. Figures 4a and 4b consist of annual rainfall prediction nomograms, each based on the prevailing coefficient of variation in the Canal Zone and Thailand, respectively.

Specific aspects of annual rainfall distributions are next compared between the Canal Zone and Thailand, such as the 10th and 90th percentiles, and the probabilities of encountering selected amounts of annual rainfall in each of the regions of interest. In addition, examples of the areal distribution of extreme annual rainfall are given for the years 1957 and 1960. The relationship between annual rainfall and runoff or monthly rainfall is examined and coincidences in the data of the Canal Zone and Thailand are noted. Implications of the observations are discussed.

2. Data sources

For the Canal Zone, most of the data were obtained from an earlier study (4), climatological summaries published by the Panama Canal Company (2), or the United States Weather Bureau (14). For Thailand, most of the annual data (Table III) were derived from a 50-year (1911-1960) summary of monthly rainfall (15) or from a shorter (1938-1960) summary of monthly and annual rainfall (5). In Table III, which lists annual rainfall for Thailand, year-by-year (1911-1960) for 45 stations, only 6

* See equation

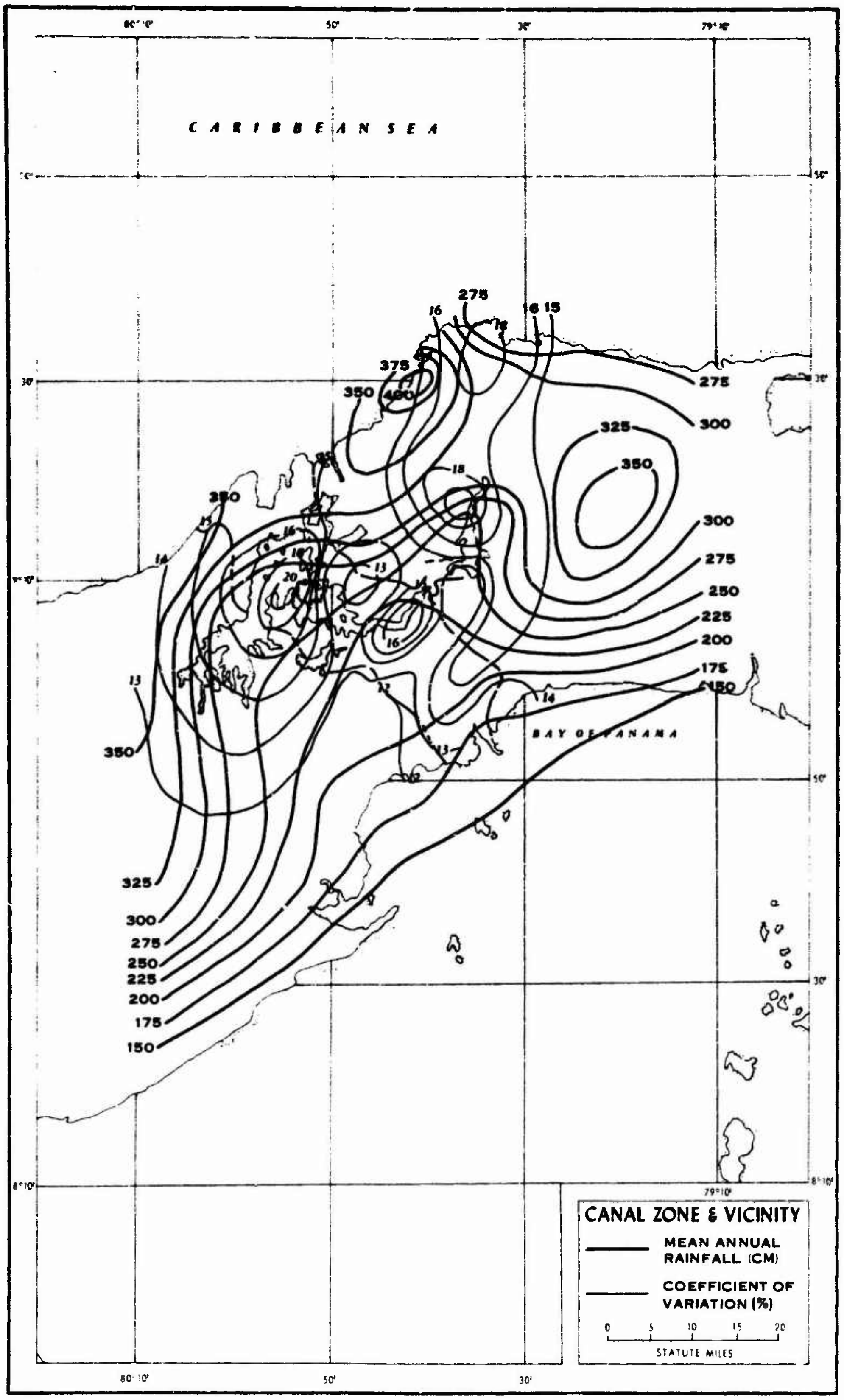

Figure 3a: Canal Zone and vicinity.

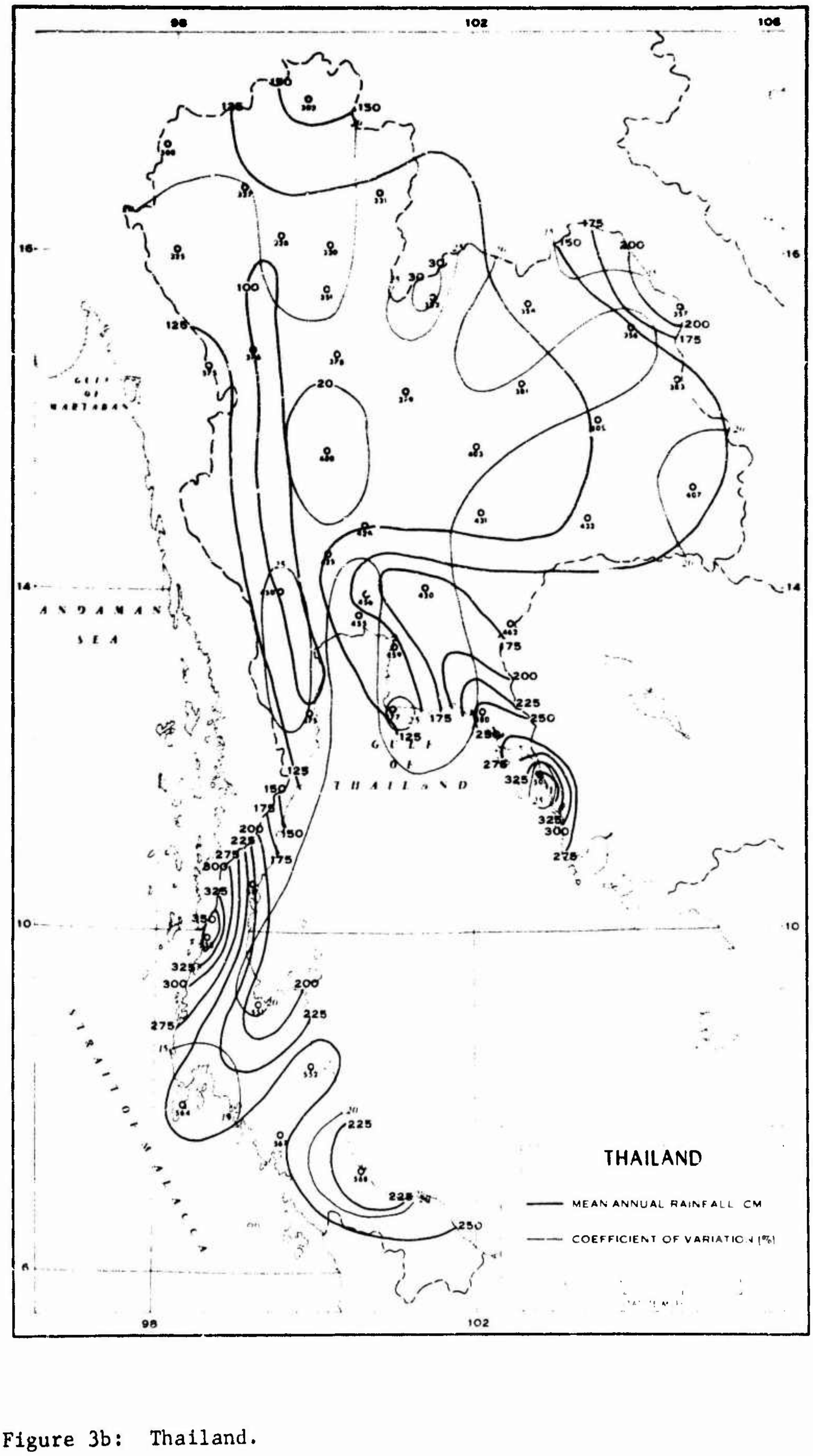

Figure 3b: Thailand.

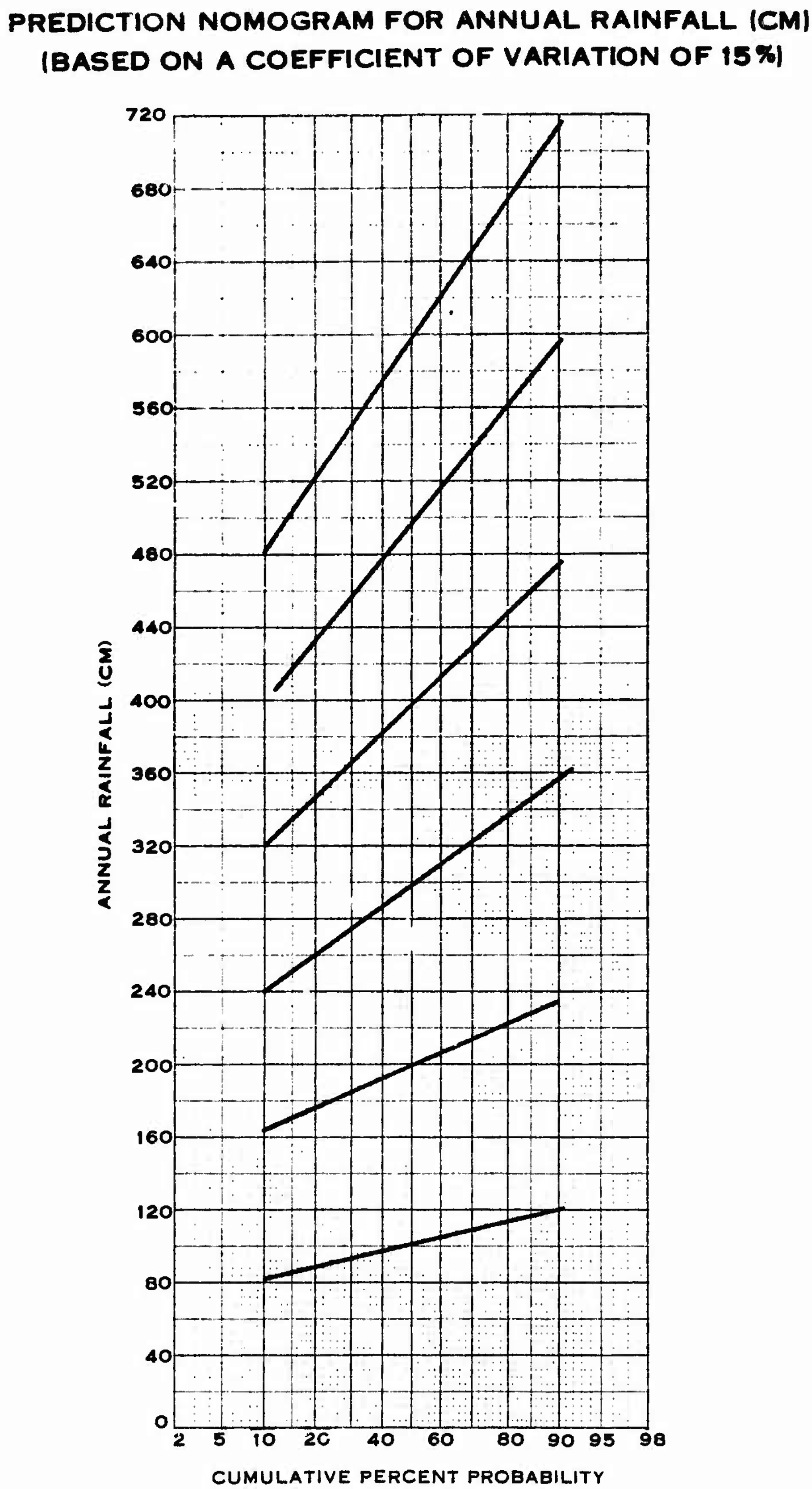

Figure 4a: Based on a coefficient of variation of 15%.

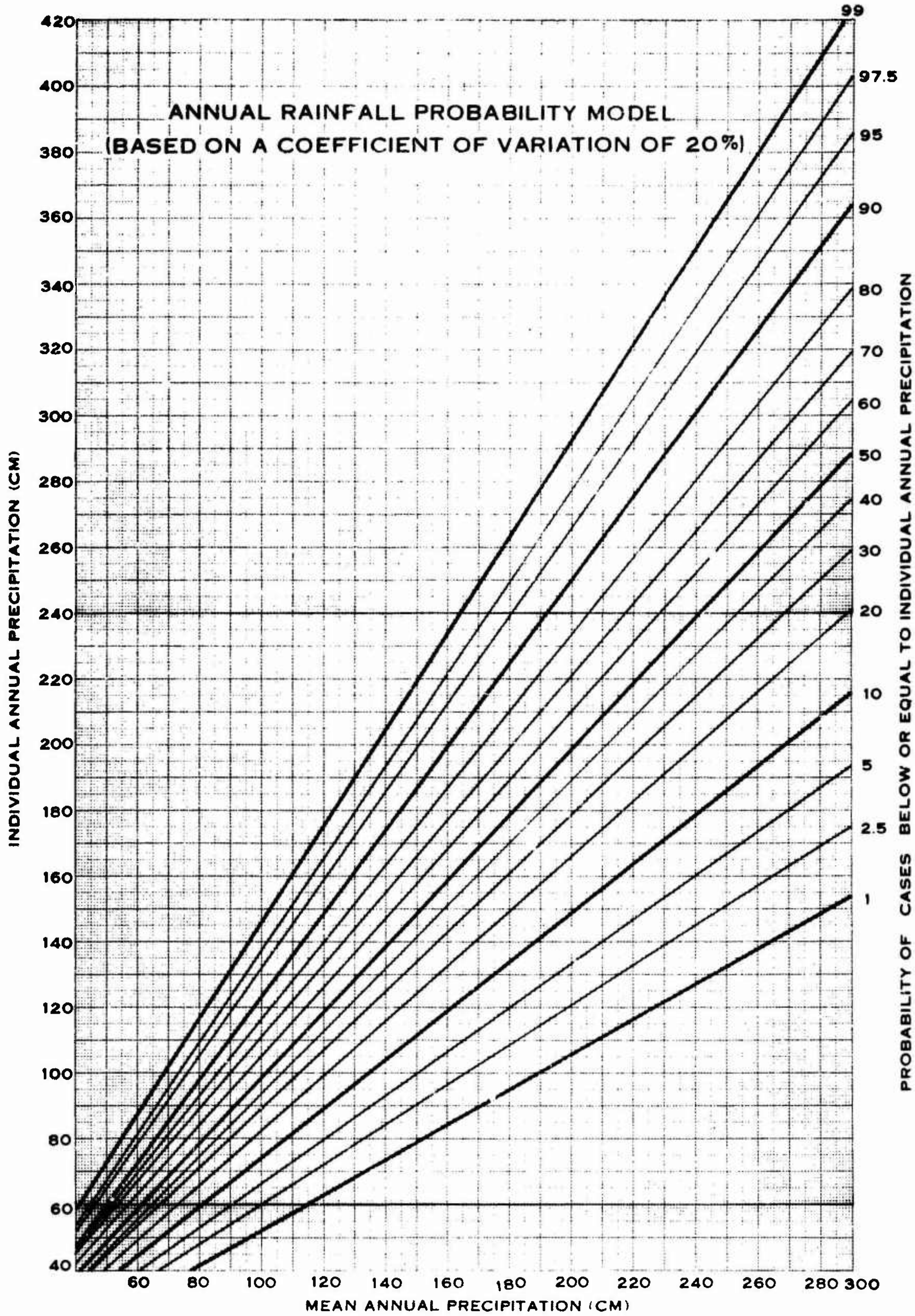

Figure 4b: Based on a coefficient of variation of 20%.

stations have complete records for 50 years, 34 stations for more than 40 years, and 37 stations for 30 years or longer. Additional data were obtained from the Monthly Bulletins of the Meteorological Department of Thailand (16). River discharge and daily rainfall data were obtained from various hydrological data books (17-19). Observations for the decade 1941-1950 (war years) were incomplete for many stations. For both areas, as well as for selected sites, data were also obtained from the World Weather Records, the U.S. Air Weather Service, or the U.S. Navy summaries (20-23).

3. General weather conditions

Earlier reports have given detailed accounts of the weather and climate of the Canal Zone (24, 25), and Thailand (5, 26), including seasonal variation of the elements. Due to its greater size and more complex topography, Thailand (Figure 1b) experiences a greater variety of weather than the Canal Zone. Both the Canal Zone and Thailand are subject to orographic rain, convective showers, shallow depressions, and easterly waves (27). Hurricanes have not been observed in the Canal Zone (25); however, typhoons occasionally penetrate Thailand. In addition, Thailand tends to be more frequently affected by the intrusion of storms from the westerlies or by interaction between the temperate and tropical weather systems. The "northers" of the Canal Zone are also of this category since they are initiated by a thrust of polar air.

Weather in the humid tropics is to a large extent influenced by the latitudinal position or configuration of the Inter-tropical Convergence Zone (ITCZ). In general, in the Northern Hemisphere, the ITCZ follows the sun in its apparent journey northward, but lags behind the sun on its apparent journey southward (25). Ideas concerning the ITCZ are constantly being revised. The surface synoptic systems associated with widespread rain over Southeast Asia may be exceedingly varied, even in a given month (28). Satellite photographs reveal the ITCZ as a sinuous band of clouds encircling the globe in the vicinity of the equator. Stormy areas alternate with relatively clear areas; easterly disturbances form and dissipate along the ITCZ. In some regions the cloud band is split into roughly parallel components. Although the ITCZ represents the confluence of the Northeast and the Southeast Trades, the associated surface pressure trough is not necessarily coincident with the wind field or the cloud patterns. Over Thailand (and the rest of Southeast Asia), the southerly or southwesterly winds south of the ITCZ constitute the southwest monsoon, which is essentially the recurved Southeast Trades. Moisture borne by these winds is the principal source of rain and humidity for Southeast Asia. Tropical cyclones generated in the Bay of Bengal sometimes serve to "trigger" the southwest monsoon (29). Recent research efforts to improve the forecast of the onset or departure (30) of the southwest monsoon seem promising.

The arrival of the ITCZ heralds the rainy season in both the Canal Zone and Thailand, accompanied by increases in humidity and cloudiness as

well as decreases in temperature. In Thailand, where transitional seasons occur, both the wet and dry seasons are shorter than their counterparts in the Canal Zone, where the wet season is a full eight months and a distinct dry season prevails the rest of the year. In the Canal Zone and Thailand peak temperatures usually occur in April, just before the onset of the rainy season The Northeast Trade inversion is much more effective in preventing winter rain in the Canal Zone than in Southeast Asia The most extensive flooding in the Canal Zone and neighboring areas in Panama is almost invariably associated with a "norther", especially toward the end of the rainy season. Storms of this nature have been analyzed in detail in connection with a study of the maximum possible precipitation over the Panama Canal Basin (25). The heaviest daily rainfall in Thailand is associated with severe tropical cyclones or occasional typhoons.

In both regions, marked changes in the frequency of amplitude of large-scale planetary waves have a profound effect on all aspects of the weather. In a recent detailed study, "Structure of an Arabian Sea Summer Monsoon System', however, the authors pointed out that the rainfall distribution seemed to be better correlated with the mid-tropospheric cyclones rather than with surface synoptic features (31) Some success has been attained in relating an hourly radar index to local noon satellite cloud patterns over Southeast Asia (32) While synoptic analysis is beyond the scope of this report, an understanding of tropical weather systems is of utmost importance in determining optimum times and locations for conducting environmental tests.

4. The statistical analysis of annual rainfall

4.1 Cumulative percent probabilities for selected stations

Figure 2 contains cumulative percent probability plots, based on 30-year records, for two stations in the Canal Zone and five stations in Thailand. In general, the distributions are approximately normal. Included in this figure are plots for Tak and Ranong, the driest and wettest stations of both areas, with mean annual rainfalls of 96 cm and 475 cm, respectively. To some extent, Bangkok is the Thai counterpart for Balboa Heights as is Chanthaburi for Cristobal, for reasons which will become more apparent later. Similar plots for most of the stations in the Canal Zone would fall between those for Trang and Chanthaburi; while such plots for most stations in Thailand would fall between those for Tak and Balboa Heights. Figure 2, which encompasses the entire range of annual rainfall regimes for the Canal Zone and Thailand, serves to compare rainfall probabilities among selected stations For the assessment of areal rainfall, however, descriptors are required for mapping. Such descriptors are therefore sought in the various statistical parameters.

4.2 Statistical parameters

Table IVa contains for three stations in the Canal Zone, the following statistics, namely: the mean, the mean deviation, the standard deviation, skewness, kurtosis, and the coefficient of variation; Table IVb contains similar statistics for 45 stations in Thailand. Table IVc contains the original "questionable" statistics for 4 of the Thai stations in Table IVb* (in which the revised statistics for these stations are given). Table IVc also includes the year in which the most extreme rainfall occurred for each of the 4 Thai stations, as well as the standard error represented by that extreme rainfall (see explanation after Table IVc).

On the whole, Table IV confirms the preliminary observations (Figure 2) that the annual rainfall of Thailand, as well as of the Canal Zone, tends to follow the normal Gaussian distribution, since

$$A \approx 0.8 \; S^{**} \qquad (1)$$

where A = mean deviation
S = standard deviation

If mean deviations are available in climatic summaries, standard deviations may thus be readily obtained from equation (1). For the most part, skewness does not depart greatly from zero, while kurtosis approaches the normal value of 3.0, ranging with few exceptions from 2.0 to 4.0. The variation of the different statistical parameters with time is next examined.

4.3 Variations of statistical parameters with time

Table V (Statistical sampling of annual rainfall) contains statistics similar to those in Table IV for 6 Thai stations, except that they are based on different intervals of time. The intervals are: 1911-1960 (Table IVb), 1911-1940, 1921-1950, 1931-1960, and 1951-1960. It is apparent from Table V that at any station the character of the rainfall distributions may decidedly change with time. The respective statistics for overlapping pairs of 30-year periods are often no closer than those between a 30-year and a 50-year period. For example, for station #379 values of skewness for the 50-year period, 1911-1960, and the 30-year

---

* Standard statistical equations (12)

** Theoretically, A = .7979 S (33)
See equation (4) after Table IVa (Appendix)

period 1931-1960 are the same, namely 0 14, whereas the values for the other two 30-year periods, 1911-1940 and 1921-1950 are 0.49 and -0.05 respectively. Kurtosis is somewhat more reproducible than skewness. Nevertheless, both these parameters are highly sensitive to singular events (see Tables IVb and IVc) Contrary to expectations, the rainfall in a single decade may sometimes be steadier than for longer periods; for all 6 stations, the coefficients of variation for 1951-1960 are less than for the 50-year period.

Some of the discrepancies observed in Table V would be anticipated from sampling theory, which states that each statistic has its own distribution (33) For instance, the mean has a normal distribution such that its standard deviation S_m may be found as follows:

$$S_m = S/\sqrt{n} \tag{2}$$

where S = standard deviation for the sample
n = number of observations

Consequently, the range of the mean may be determined for different percents of time, or confidence limits.

The range of the mean for 90% confidence limits, based on data for the 30-year and 10-year intervals is included in Table V The results show that the decade 1951-1960 was unusually wet for Suphan Buri (#425), Bangkok (#455), and Chanthaburi (#480); for these cases the range of the mean entirely exceeded the 50-year value. Due to that decade, the 30-year records for 1931-1960 were similarly biased for both Bangkok and Chanthaburi. On the other hand, the period 1911-1940 was so dry at Bangkok that the range of the mean fell entirely below the 50-year value Despite the fact that at least two-thirds of the 30-year intervals differed significantly from the long-term periods, even in the most extreme situations, departures of the mean of the sample from the long-term mean were not greater than 15% for 90% of the time. The range of the standard deviation was also determined for the different intervals in Table V for 90% confidence limits (33). The long-term value of the standard deviation was found within these limits in all instances.

4.4 The selection of universal descriptors of annual rainfall

Since from a practical viewpoint station identities are generally maintained through the means and the standard deviations derived from periods of 30 years (or longer), these parameters may be used for the overall comparisons or annual rainfall regimes, even from inhomogeneous data. However, it is recommended that the standard deviation be expressed as a percent of the mean, that is, as the coefficient of variation, for reasons given below Figures 3a and 3b are maps of the selected universal descriptors, namely the means and coefficients of variation, of annual rainfall for the Canal Zone and Thailand, respectively.

Some advantages of expressing the standard deviation in terms of the coefficient of variation in describing annual rainfall regimes are as follows:

(1) Often fairly extensive areas with a range of standard deviations have the same or similar coefficients of variation (which therefore may be easily remembered) as shown in Figures 3a and 3b, as well as in earlier investigations (10, 11).

(2) A prediction nomogram based on a prevailing coefficient of variations for a given area may be constructed, as Figures 4a or 4b.

(3) Since maps, such as Figures 3a and 3b, have universal application, that is, may be used for the comparison of annual rainfall regimes over the world, the information given may also provide a clue to the number of days of rain in some cases. For instance, Hershfield (10) obtained an inverse relationship between the number of days and the coefficient of variation of annual rainfall in the United States (in the Arizona-Nevada desert, coefficients of variation of 60% have been found).

(4) Theoretically, the coefficient of variation is a measure of reliability of a given variable, irrespective of amount.

4.5 Prediction nomograms for annual rainfall

A general-purpose prediction nomogram for annual rainfall may accomodate changes of both skewness and the coefficient of variation with the magnitude of annual rainfall (34). However, in the Canal Zone and Thailand, skewness is not very great; nor is there any marked relationship between the coefficient of variation and the magnitude of annual rainfall. Consequently, in the prediction nomograms presented here (Figures 4a and 4b) the assumption is made that the median is essentially equal to the mean.

Figure 4a is a nomogram based on a coefficient of variation of 15%, a value which characterizes the annual rainfall over a substantial area in the Canal Zone, especially in the vicinity of Balboa Heights and Cristobal, as well as a limited area in Thailand. Figure 4b, another version of a prediction nomogram, is based on a coefficient of variation of 20%, a value which characterizes the annual rainfall over much of Thailand and a limited area in the Canal Zone.

From the above nomograms, the following may be readily estimated:

(1) the annual rainfall to be equalled or exceeded for a given percent of time;

(2) the percent of time that annual rainfall will be less than or equal to a given amount;

(3) the percent of time that annual rainfall within a given range might be expected to occur.

5. Analogous rainfall regimes

Thai stations with rainfall regimes somewhat analogous to that of either Balboa Heights or Cristobal are listed below

	Stations	Mean annual rainfall (cm)	Coefficient of variation (%)
	BALBOA HEIGHTS, C Z	175*	13
Most closely analogous Thai stations	Chiang Rai	164	18
	Don Muang	155	16
	Aranyaprathet	154	18
Next closest analogous Thai station	Bangkok	142	17
	CRISTOBAL, C.Z.	325*	15
Most closely analogous Thai station	Chanthaburi	283	20
Next closest analogous Thai station	Narathiwat	268	18

* Rounded off to nearest 5 cm (corresponding to tens of inches)

The stations labelled "most closely analogous" have coefficients of variation within 5% of that of the respective test site and mean annual rainfall within 5 cm of that of Balboa Heights or within 50 cm of that of Cristobal. The criteria for analogy are more or less dictated by the observations. Closer analogies, on the basis of the above descriptors, do not exist between a Thai station and either of the two test sites in the Canal Zone Bangkok and Narathiwat are the "next closest" analogous stations to Balboa Heights and Cristobal, as listed above.

Analogous areas ("most closely") are contained within the isohyets 150 cm to 200 cm and 275 cm to 375 cm on the maps of the mean and the coefficient of variation of annual rainfall in Figures 3a and 3b, respectively.

6. Applications of the results

6.1 The 10th and 90th percentiles of annual rainfall

Figures 5a and 5b are maps of the 10th and 90th percentiles of annual rainfall, respectively, for the Canal Zone. Figures 5c and 5d are similar maps for Thailand. For the Canal Zone and vicinity, the 10th percentiles range from about 150 cm at Balboa Heights to about 275 cm at Cristobal. Except for the Peninsula and Chanthaburi, the 10th percentiles for most of Thailand are below 150 cm. The relatively dry station of Balboa Heights in the Canal Zone is wetter than most stations in Thailand the majority of the time. However, the 10th percentiles of some of the foot-hill stations facing the southwest monsoon reach as high as 325 cm.

The 90th percentiles for the Canal Zone range from 200 to 400 cm, but for most of Thailand they are less than 200 cm except at the foot-hill stations, where 500 cm or more is attained. In the Khorat Plateau and Chao Phya Plain in Thailand (Figure 1b), the 90th percentiles are about equivalent to the 10th percentile at Balboa Heights. Only in limited sections of Thailand does the 90th percentile approximate or at times exceed the 10th percentile of Cristobal.

6.2 The percent probability of encountering given amounts of annual rainfall

Figures 6a to 6d give the percent probabilities of encountering annual rainfall equal to or greater than 200 cm for the Canal Zone, and equal to or greater than 100 cm, 150 cm and 200 cm, respectively, for Thailand. The 100 cm and 150 cm data have been omitted for the Canal Zone where these amounts are invariably exceeded.

The probability that annual rainfall greater than 200 cm will occur in any year is more than 80% for much of the Canal Zone and less than 20% for much of Thailand (Figures 6a and 6d).

6.3 Examples of areal distributions of extreme rainfall: 1957 and 1960

Since the areal extent of extreme rainfall is of importance for field operations, the extreme years* of 1957 and 1960 were analyzed for both the Canal Zone and Thailand. In the Canal Zone, in 1957, the year of the "Great Caribbean Drought", all departures from normal were negative (2). In 1960, an extremely wet year, all departures from normal were positive (2). One of the largest floods on record occurred on the

* Not necessarily the most extreme years on record; 1935 was wetter for the Canal Zone.

upper Chagres River at the Chico station on January 1, 1960 (2). Figure 7 expresses the annual rainfall for each case in terms of percentile ranks. Figure 7a and Figure 7b are maps showing percentile ranks of annual rainfall in the Canal Zone for 1957 and 1960, respectively In 1957 most of the rainfall was below the 20th percentile (Figure 7a), whereas in 1960, it was mostly above the 80th percentile (Figure 7b). Figures 7c and 7d are maps showing percentile ranks of annual rainfall in Thailand for 1957 and 1960, respectively. In 1957 excessive precipitation, equal to or greater than the 80th percentile, occurred over a large area of south-central Thailand, including Bangkok, while unusually low rainfall, less than the 20th percentile, occurred in the north-central and north-eastern sections as well as the east coast of the peninsula (Figure 7c). In 1960 the pattern was nearly the reverse, with very low rainfall throughout central Thailand and excessive rainfall in limited areas in the north-east and northwest (Figure 7d). However, in this year the east coast of the peninsula also experienced less than normal rainfall, but not quite as low as in 1957.

Due to its relatively large size (Figure 1b) then, even in extreme years, the departures of annual rainfall from normal in Thailand varied in sign in different parts of the country. In the Canal Zone, in more moderate years, as 1958 and 1959, departures from normal also varied in sign from one section to another (2). In these years, also, the internal variations in annual rainfall were generally much less than for 1957 and 1960.

6.4 Annual rainfall and runoff

The occurrence of extreme rainfall in any year may often be deduced from the total annual runoff. Although runoff depends on a number of variables (35), including temperature, wind, soil properties, topography, rainfall remains the basic factor.

Table VI compares the total runoff of the Gatun Lake Drainage Basin for the years 1957-1962 with rainfall at Gatun Even at a single site, some correlation is apparent between extreme rainfall and extreme runoff. In 1957 the runoff was about half that of 1960, while the percentile ranks of the annual rainfall were 15 and 93, respectively

Table VII compares rainfall, runoff, gage heights, dates of the maximum daily gage height and duration of the rainy season for 1960-1965 at Ubon, Thailand, on the Mae Nam Mun, one of the tributaries of the Mekong. In 1965 the total annual runoff was about 40% of the value for 1962, while the percentile ranks of annual rainfall were 28 and 96, respectively. On 22 days in 1962 the gage height exceeded 10 m, whereas in 1965 the maximum height was only 4.8 m Despite the year-to-year variations in the onset of the monsoon or in the amount of total rainfall, the maximum daily gage height each year invariably occurred in October.

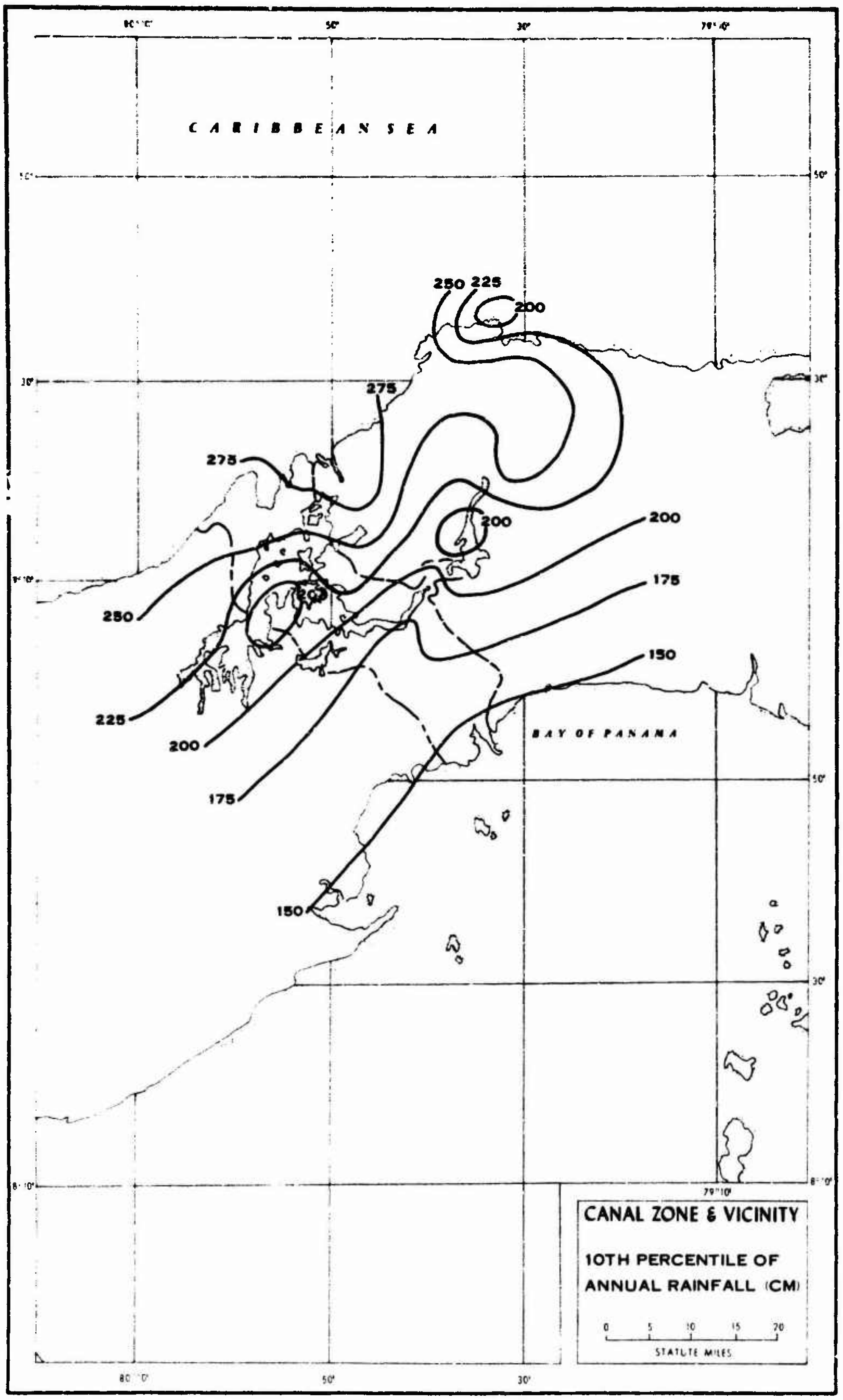

Figure 5a: 10th Percentile, Canal Zone and vicinity.

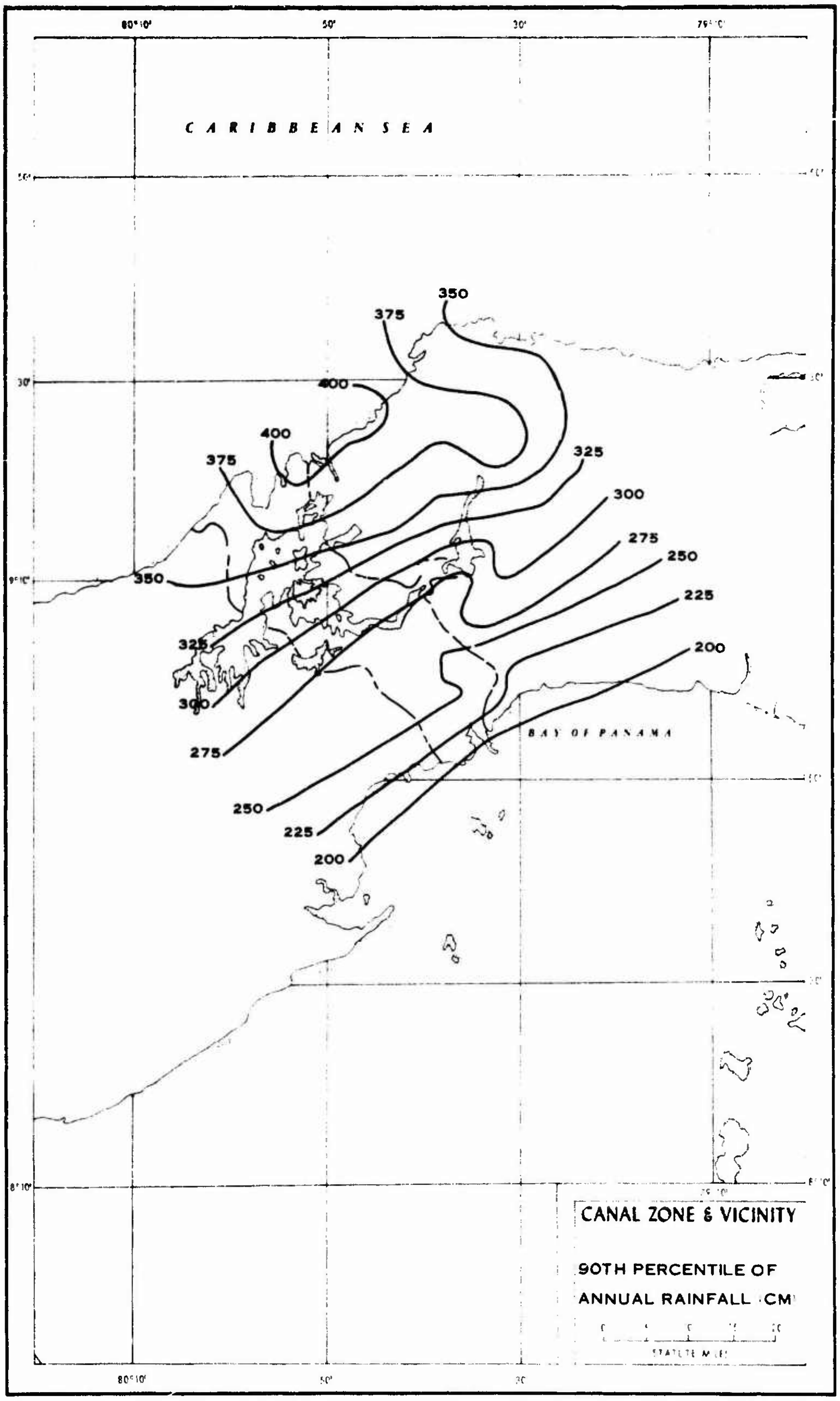

Figure 5b: 90th Percentile, Canal Zone and vicinity.

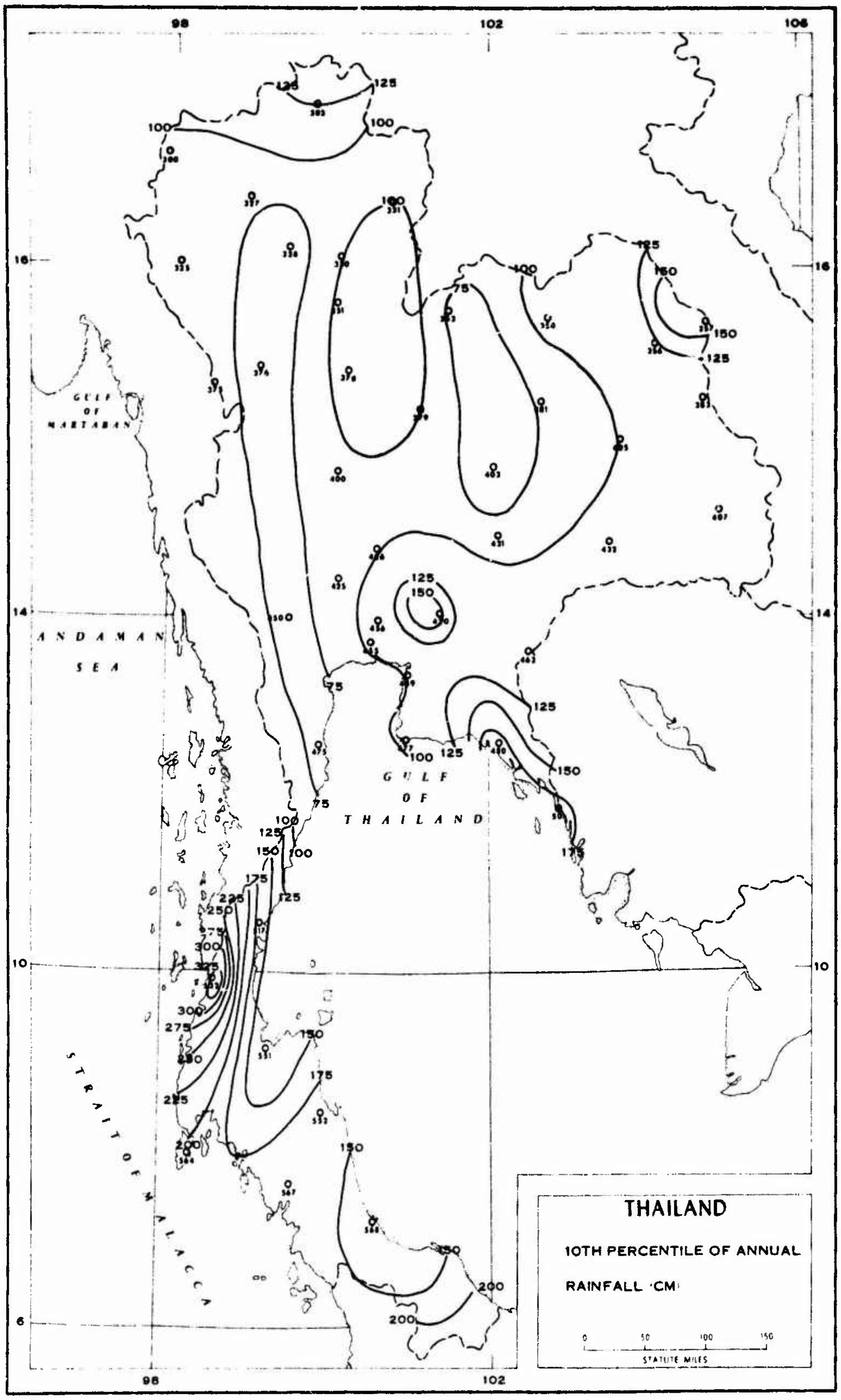

Figure 5c: 10th Percentile, Thailand.

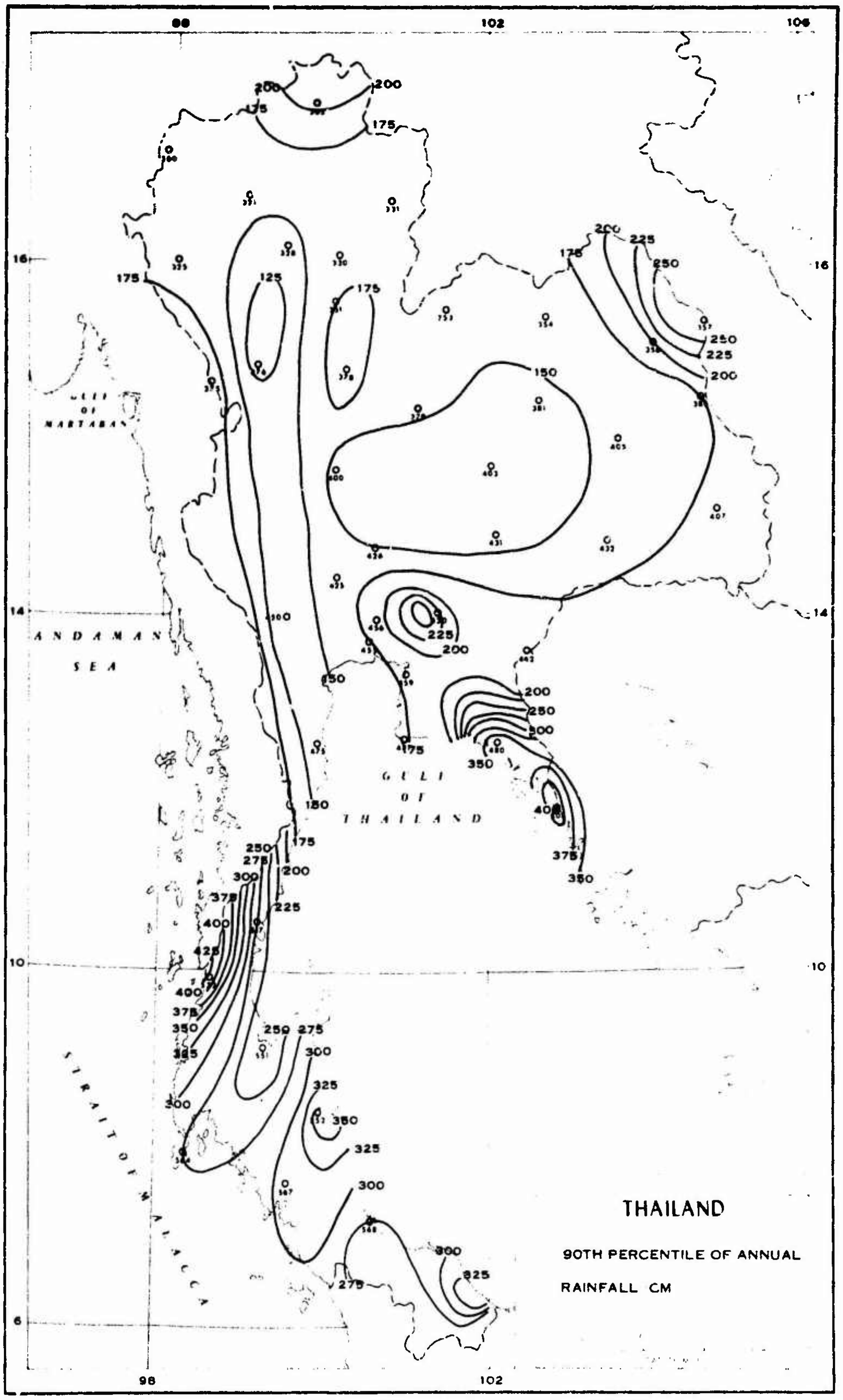

Figure 5d: 90th Percentile, Thailand.

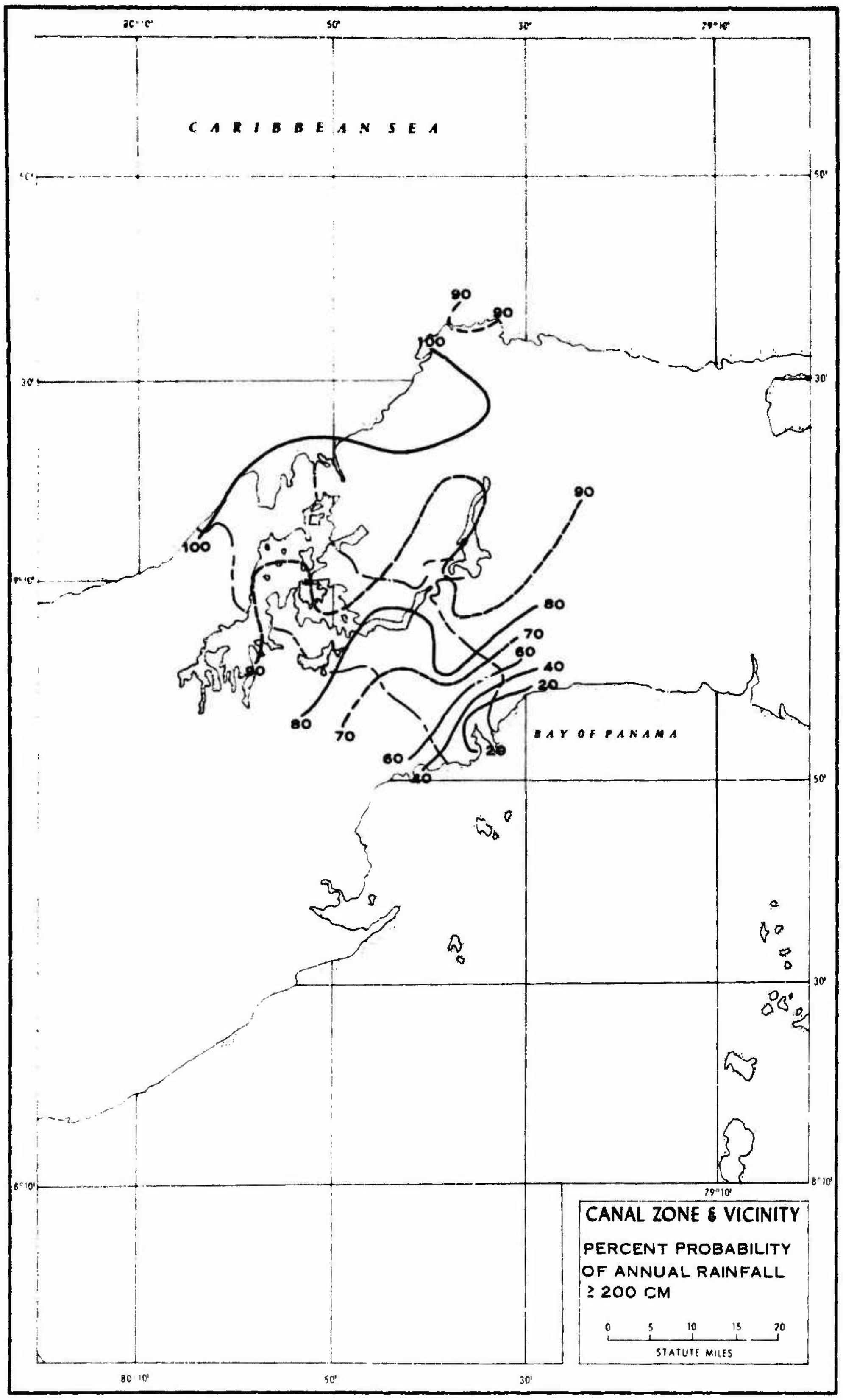

Figure 6a: 200 cm, Canal Zone and vicinity.

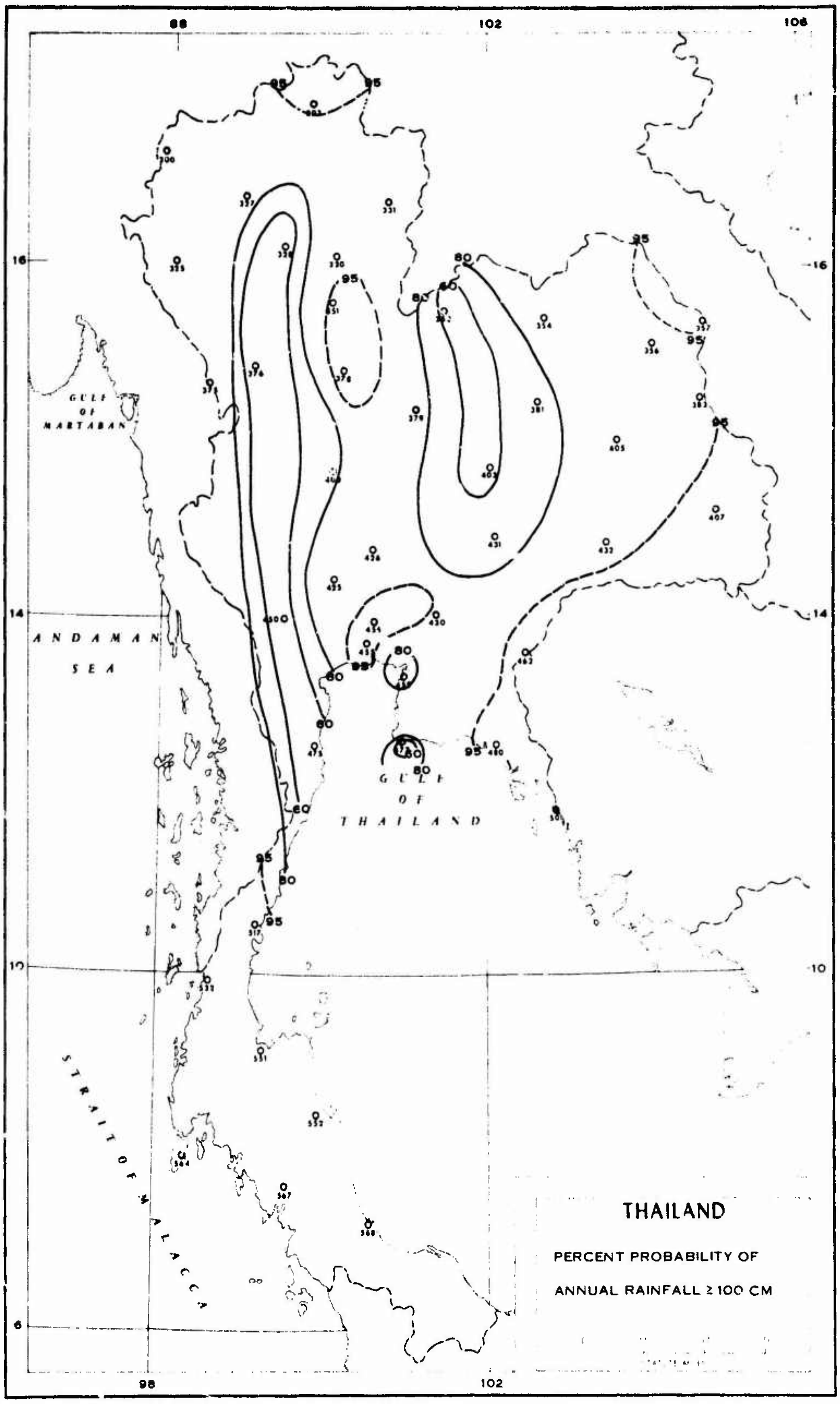

Figure 6b: 100 cm, Thailand.

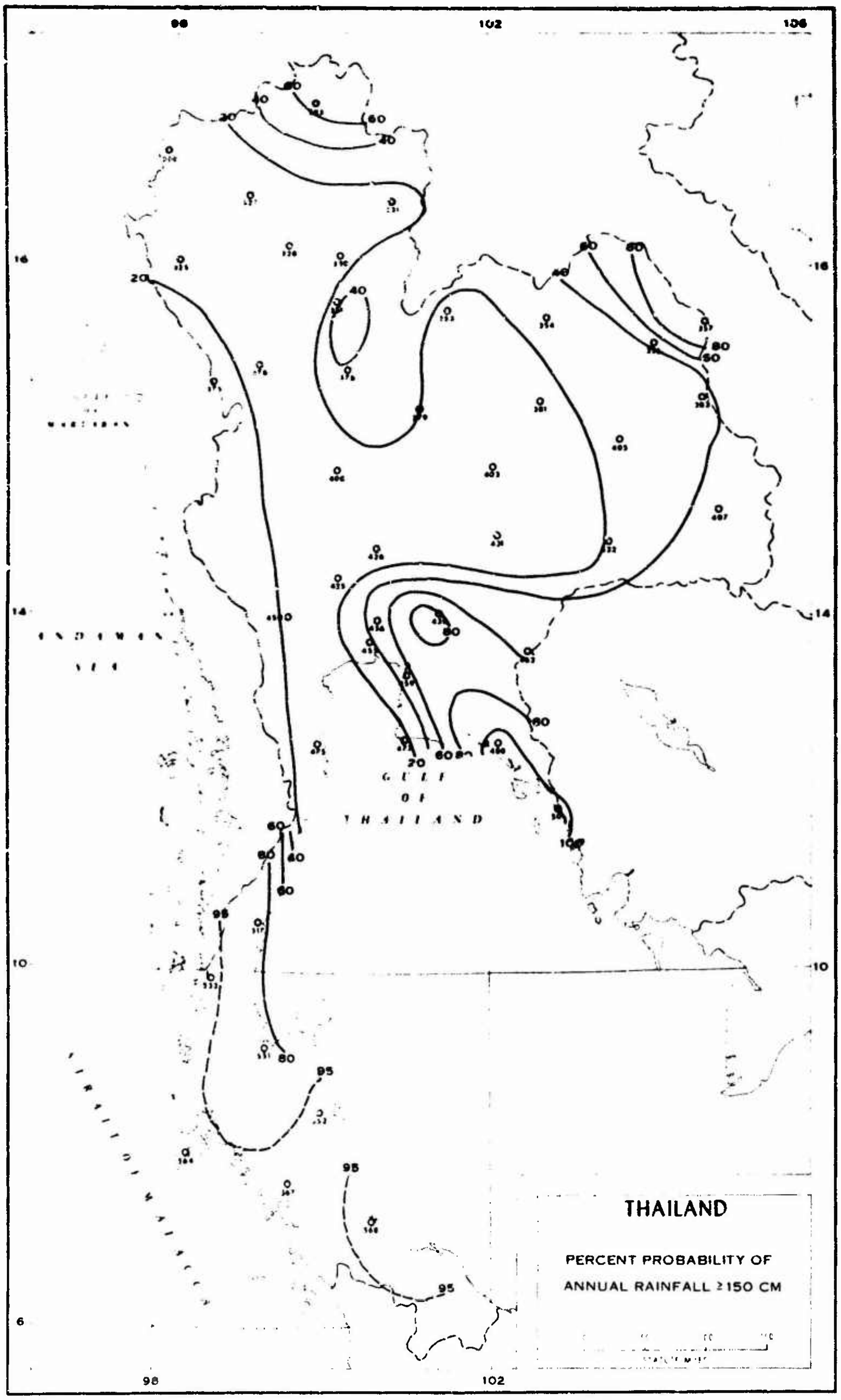

Figure 6c: 150 cm, Thailand.

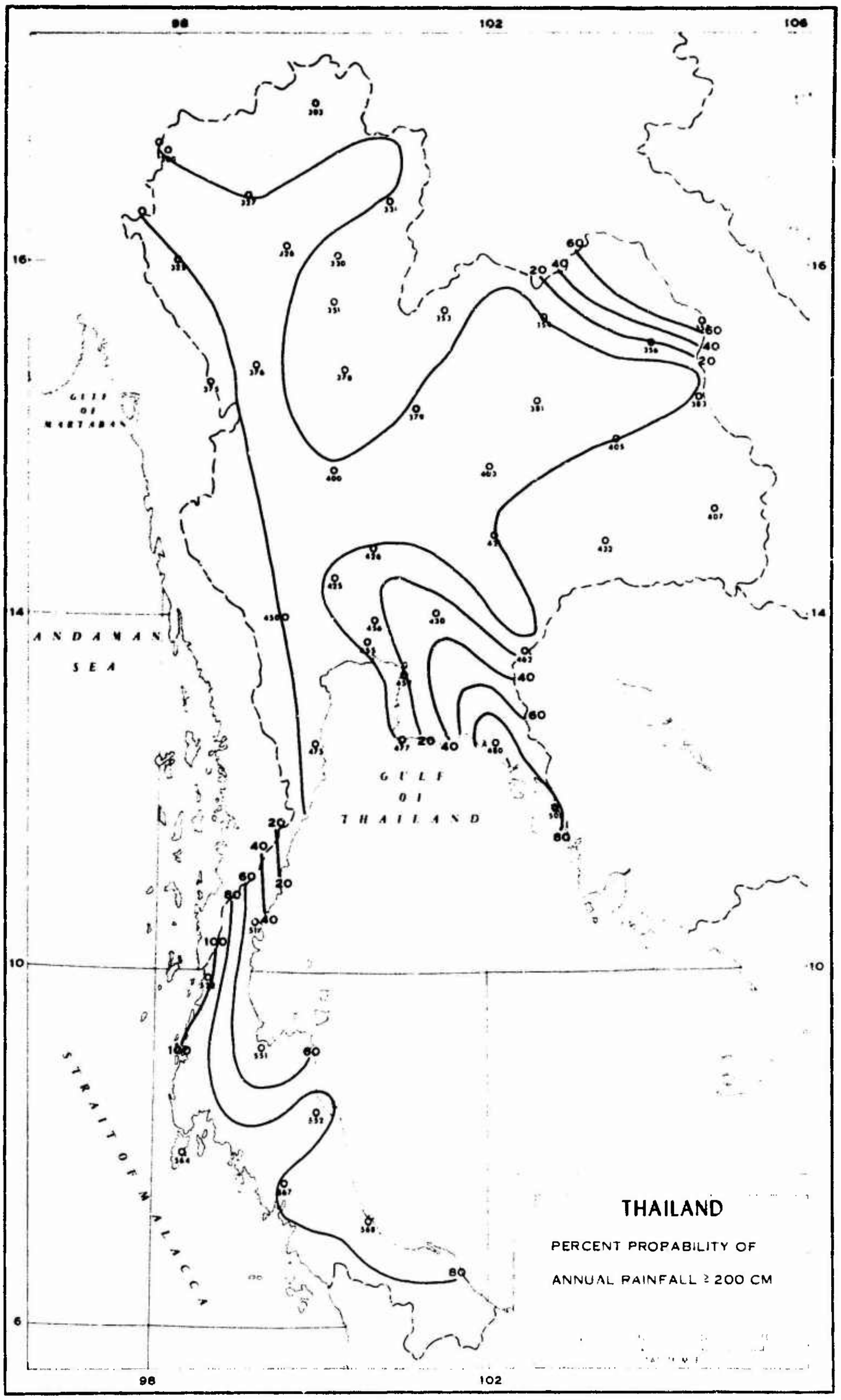

Figure 6d: 200 cm, Thailand.

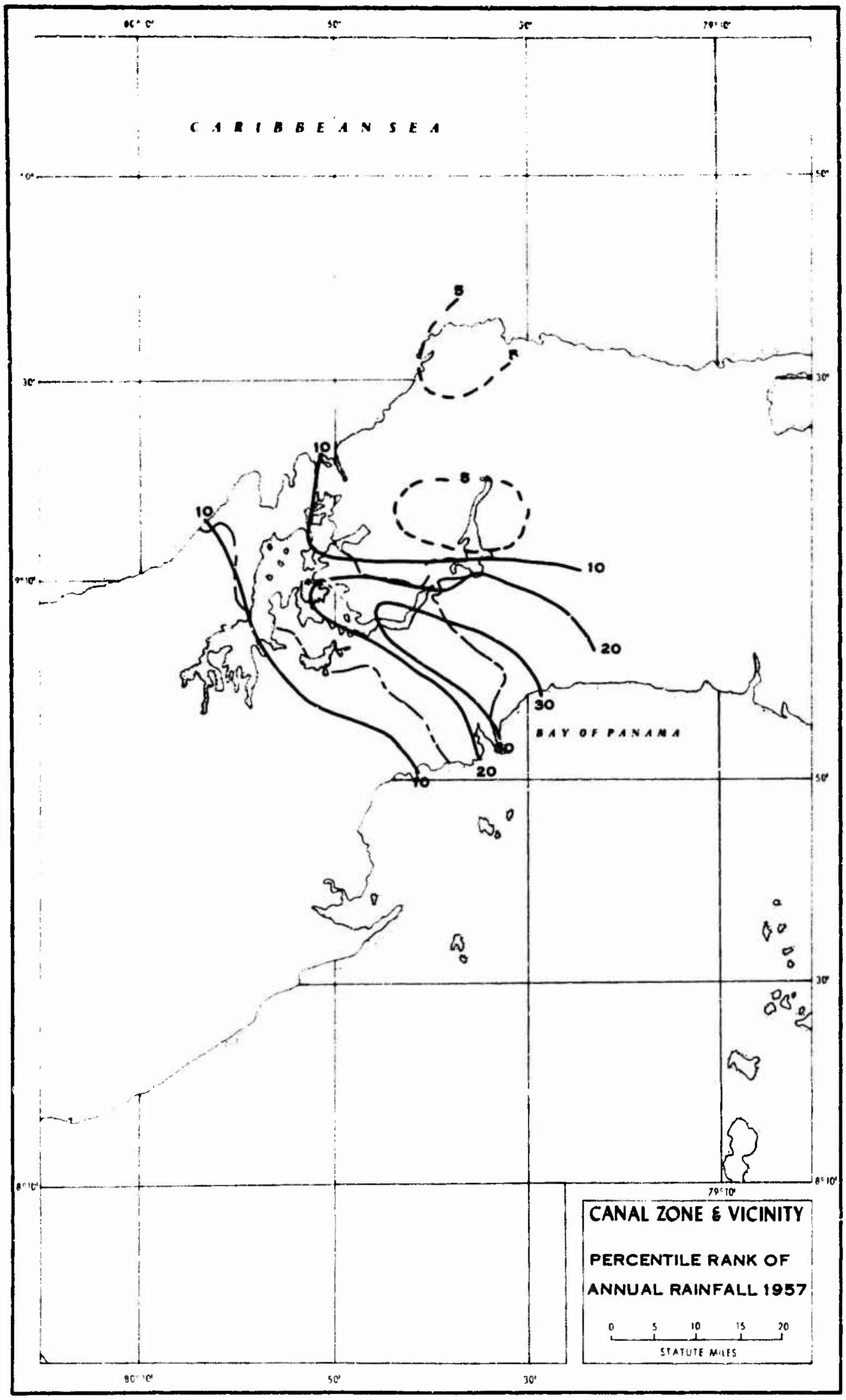

Figure 7a: 1957, Canal Zone and vicinity.

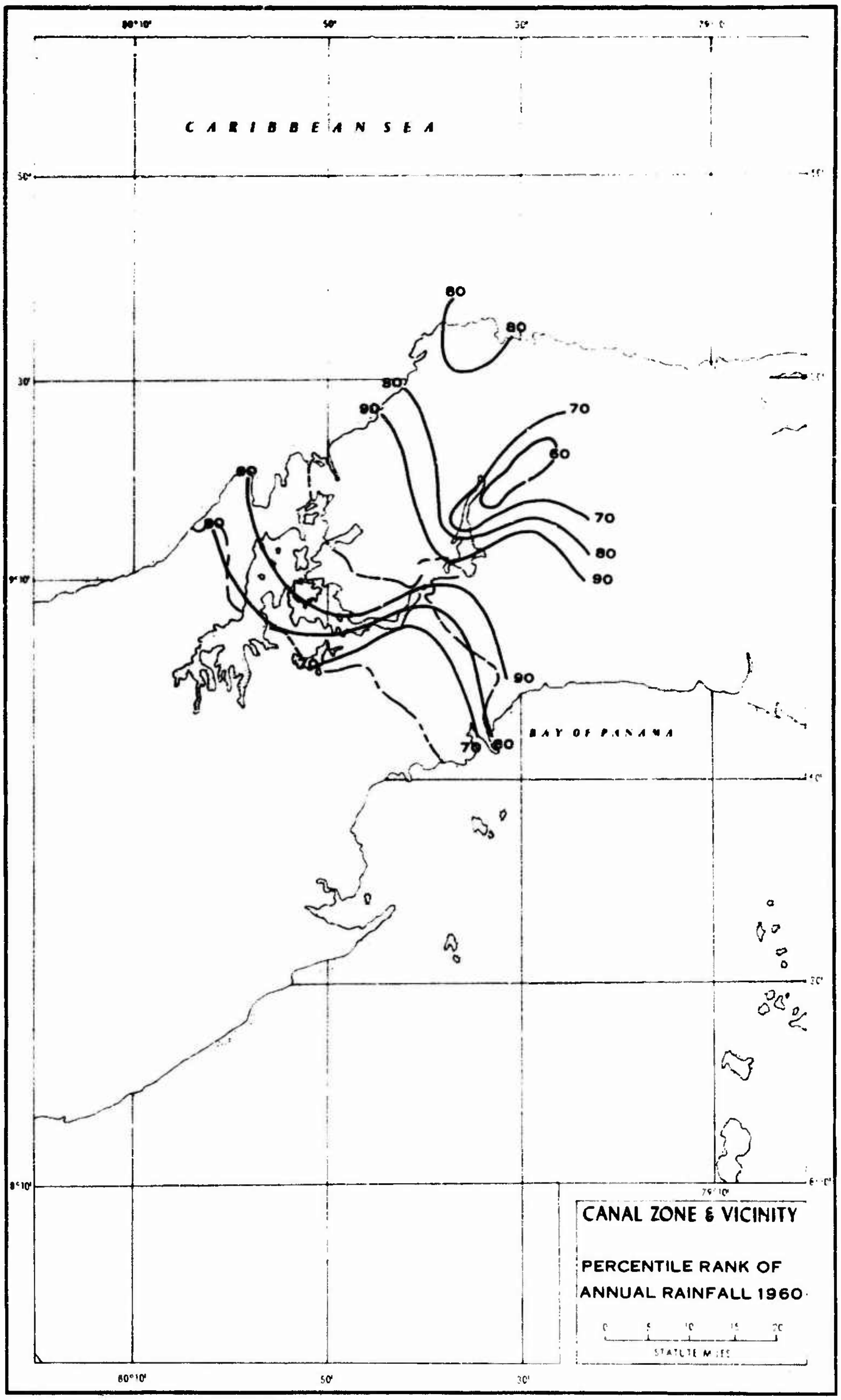

Figure 7b: 1960, Canal Zone and vicinity.

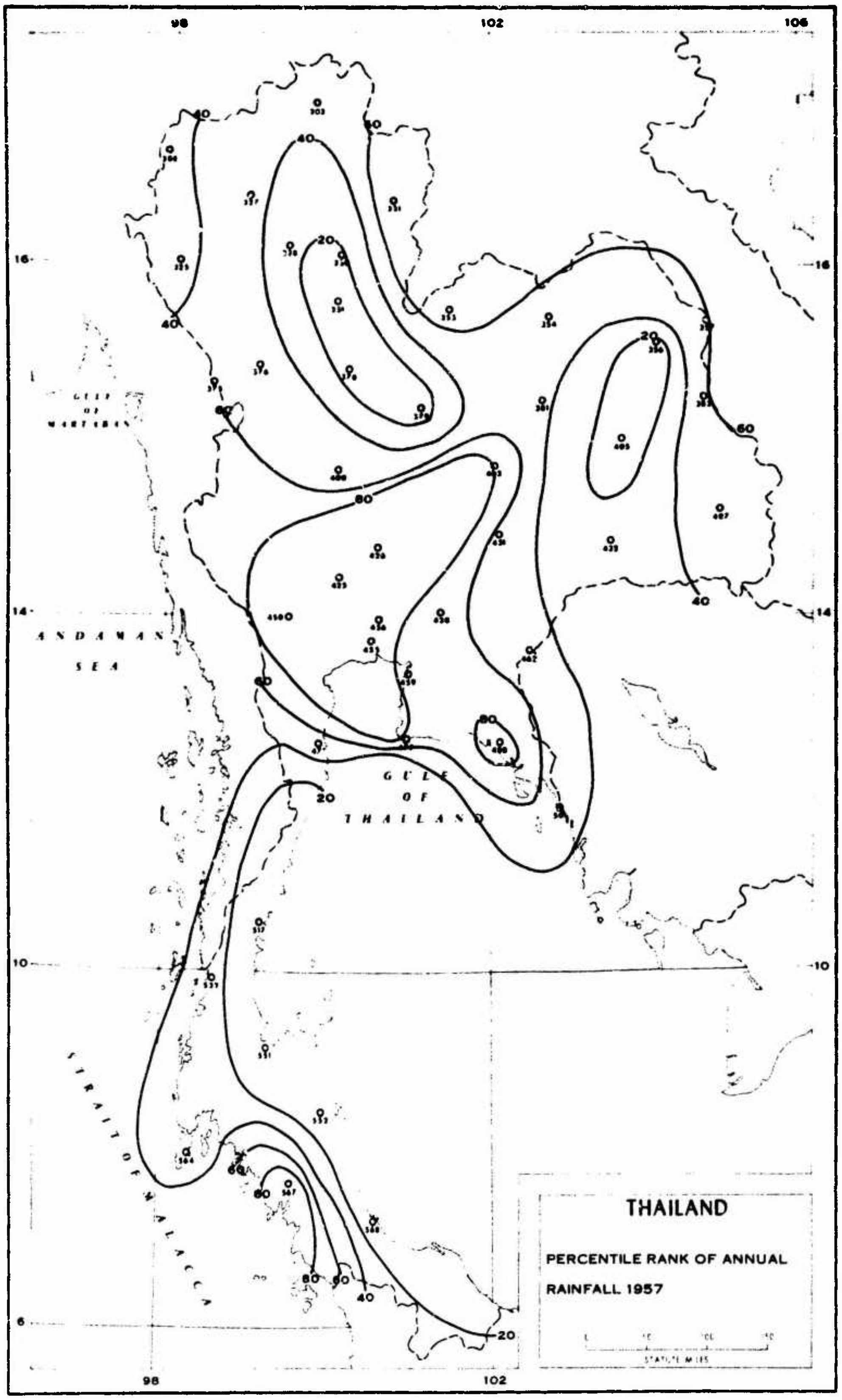

Figure 7c: 1957, Thailand.

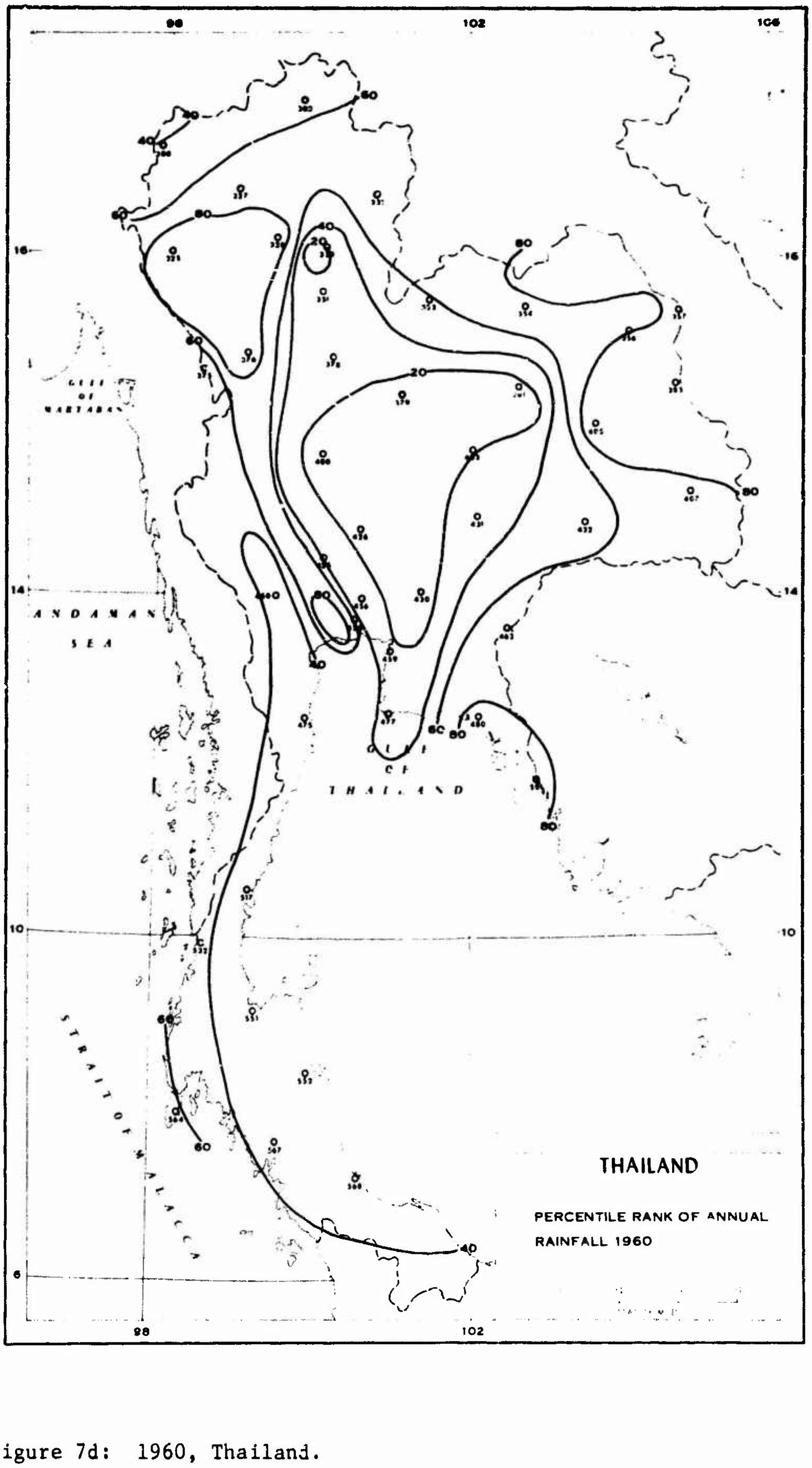

Figure 7d: 1960, Thailand.

6.5 The relationship of monthly to annual rainfall

The relationship between monthly and annual rainfall is of interest for the following reasons.

(1) To ascertain if analogous annual rainfall regimes are analogous on the monthly level

(2) To determine to what extent changes in the total annual rainfall are reflected in the monthly rainfall distributions.

(3) To seek clues early in the rainy season for anticipating an extreme rainfall year.

Annual rainfall and its associated monthly rainfall distribution were compared year-by-year over a 30-year period (1931-1960) for both Cristobal and Chanthaburi For this interval the mean annual rainfall for Cristobal was 342 cm and for Chanthaburi, 311 cm. At Cristobal, 1935 was the wettest year and 1948 the driest; at Chanthaburi, 1945 was the wettest and 1931 the driest.

6.5.1 Duration and regularity of the rainy season

If, for the above two stations, the 25 cm (10") isopleth is taken to define the rainy season*, the duration of the season is about 8 months (May through December) at Cristobal and 6 months (May through October) at Chanthaburi Within this season, individual months may have less than 25 cm of rain In order for the monthly rainfall at Cristobal to attain the same average as that at Chanthaburi, the annual rainfall at Cristobal would have to be about 1.33 that of Chanthaburi, that is, about the same as the ratio of the respective durations of the rainy seasons. The actual ratio of the two annual rainfalls for the interval selected is only about 1 1 However, the ratio of annual rainfall of Balboa Heights/ Bangkok = 1.33 Problems may arise in defining the length of the rainy season, which is not always clear-cut or may be subject to various interpretations (36)*.

The most salient feature of the monthly rainfall at Cristobal is its relative stability The peak month is November in 2 years out of 3 and either November or October in 5 years out of 6 During 1931-1960 peak monthly rainfall was never attained in June, July, August or September at Cristobal. On the other hand, at Chanthaburi, peak monthly rainfall is more evenly distributed over the rainy season, occurring during 1931-1960

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* At Balboa Heights or Bangkok, for example, the limiting isopleth for the rainy season may be taken to be 12 5 cm.

at least once in all months from May to November, 8 times in July, and 6 times each in June, August, and September*. As a consequence, monthly means show a November peak for Cristobal of 62 cm, which is higher than the September peak of 56 cm for Chanthaburi. Due to the combination of circumstances described, however, individual monthly extremes are actually somewhat greater at Chanthaburi than at Cristobal. Monthly rainfall exceeded 75 cm on 22 occasions at Chanthaburi, but only 10 times at Cristobal during the 30-year interval.

6.5.2 Monthly rainfall as a percent of annual

Table VIII lists the average annual precipitation for successive ranges of quintiles, and the associated mean monthly rainfalls expressed as percents of the annual rainfall for Cristobal and Chanthaburi. At Cristobal, the average May rainfall for quintile range > 80% in actual value is about 42 cm compared to about 25 cm for quintile range 40-60%. At Chanthaburi, the average June rainfall for quintile range > 80% is 73 cm, compared to 41 cm for quintile range 20-40%. Consequently, a clue to the possibility of an extreme wet year may appear as early as May or June at either station.

An exception to the above trends may be found in those years in which the monthly extreme for the entire period occurred. At neither Cristobal nor Chanthaburi did the greatest monthly precipitation over the 30-year period take place in the wettest year, but instead in a year with rainfall equivalent to the 60th percentile. Evidently different scale circulation patterns are involved in the case of the annual and monthly extremes. A single storm may sometimes cause peak monthly rainfall.

6.5.3 Coincidences observed in the data for these stations

In the course of this investigation, the coincident occurrences of extreme conditions at widely separated locations are noted as possible examples of "teleconnections", as for example, extreme annual rainfall in the Canal Zone and Thailand for both 1957 and 1960. The term "teleconnection" refers to "the favored modes for coupling large-scale abnormalities of atmospheric circulation as determined statistically or empirically" (37). Such coupling links have been noted since 1923 (37).

A number of coincidences in the data for Cristobal and Chanthaburi are noted, even though these stations are located in opposite hemispheres. For instance, the year 1936 represents the 13th percentile of annual rainfall at both stations; likewise, the years 1938 and 1960, respectively,

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* This station is not necessarily typical of the rest of Thailand, where peak monthly rainfall for most stations tends to be in September, particularly poleward of 13° N

represent the 87th and 94th percentiles at both stations. At Chanthaburi, the peak monthly rainfall occurred in 1935, the wettest year for Cristobal. At each of the stations, July 1935 was the wettest July of the 30 years. October 1952, the wettest October in 30 years at Chanthaburi, was the third wettest October at Cristobal. (This was also the driest October in 63 years over the entire United States (38), possibly a related phenomenon.*)

7. Summary

Comparisons of annual rainfall regimes in the Canal Zone and Thailand are carried out by means of statistical analysis. The universal descriptors selected consist of the mean and the coefficient of variation of annual rainfall. A single value of the coefficient is often applicable to fairly large areas. Nomograms based on these criteria are provided for design estimates of annual rainfall. In addition to the overall comparisons of rainfall regimes, specific aspects of annual rainfall distributions are also compared.

Throughout the Canal Zone, especially the coastal regions in the vicinity of the test sites, the coefficients of variation are close to 15%, while 20% prevails for much of Thailand, including some of the coastal zones. The lower values of the coefficients of variation in the Canal Zone are attributed to the greater persistence of the local winds there than in the larger, more complex topographical land mass of Thailand.

The probability that annual rainfall greater than 200 cm will occur in any year is greater than 80% for most of the Canal Zone, but less than 20% for much of Thailand. Examples of rainfall maps for extreme years are included to show the areal distribution of possible stress conditions.

Observations for Cristobal and Chanthaburi indicate that monthly rainfall, when expressed as a percent of annual, tends to remain roughly constant despite the magnitude of the annual rainfall. For these stations, therefore, it should be possible to forecast extremely wet years merely on the basis of monthly trends just after the onset of the rainy season. Stations with analogous annual rainfall regimes do not necessarily have analogous monthly rainfall regimes, unless the durations of the rainy seasons are the same, other factors (as temporal distributions) remaining constant.

In the course of this investigation, coincidences in the occurrence of extreme rainfall in the Canal Zone and Thailand are noted. Marked

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*The dry October over the U.S. was associated with a persistent ridge of high pressure on the west coast (38); whereas the wet October of 1952 at Chanthaburi was caused by a series of three typhoons.

perturbations in the global circulation are evidently responsible for these situations. An increased understanding of the nature and frequency of the large-scale wind flow patterns is essential for test planning.

In conclusion it may be stated that in Thailand rainfall regimes analogous to those in the Canal Zone, though occurring in limited sections of that country, are actually represented by areas much greater in actual size than their counterparts in the Canal Zone. Furthermore, a given physiographic province or climatic zone may encompass very different annual rainfall regimes. Conversely, similar rainfall regimes may occur in widely different physiographic provinces. Consequently, the probability charts and tables presented here should provide quantitative information more tractable for the purposes of long-range planning than that obtained from conventional climatic categories.

It is recommended that severe stress conditions which might result from the deficiency or excess of rainfall over extensive areas, as shown for the years 1957 and 1960, be systematically investigated and that critical rainfall levels be established for particular drainage basins or strategic areas. (The latter has been briefly considered here in the association of rainfall with runoff for selected cases.) Most important of all is the need for relating synoptic weather systems to extreme conditions so that stress resulting from rainfall may be more reliably predicted in real time.

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A P P E N D I X

TABLE I*

STATION INDEX, CANAL ZONE AND VICINITY

Station	Lat. (N)	Long. (W)	Elevation (m)
Balboa	8° 58'	79° 34'	9
Balboa Heights	8 58	79 33	30
Barro Colorado	9 10	79 50	64
Bohio	9 11	79 53	34
Candelaria	9 23	79 32	101
Cano	9 04	79 49	34
Chico	9 16	79 31	122
Chilibrillo	9 12	79 37	61
Cocoli	8 59	79 37	21
Coco Solo	9 22	79 53	4
Cristobal	9 21	79 55	12
Cucherbo	9 02	79 58	30
Frijoles	9 11	79 48	30
Gamboa	9 07	79 42	34
Gatun	9 16	79 56	29
Gatun River	9 16	79 46	30
Isla Grande	9 38	79 34	73
Madden Dam	9 12	79 37	76
Madronal	9 14	79 37	61
Monte Lirio	9 14	79 51	85
Pedro Miguel River	9 03	79 37	30
Peluca	9 23	79 34	107
Portobello	9 32	79 40	5
Rio Indio	9 13	79 32	64
Saddle Five	9 12	79 36	85
Salamanca	9 19	79 35	82
Summit	9 04	79 39	82
Trinidad	9 07	80 02	---

* Reference 2-4

TABLE II*

STATION INDEX, THAILAND
(in order of Index number)

Index No.	Station	Lat. (N)	Long. (E)	Elevation (m)
300	Mae Hong Son	19° 18'	97° 50'	271
303	Chiang Rai	19 55	99 50	416
325	Mae Sariang	18 10	97 50	314
327	Chiang Mai	18 47	98 59	314
328	Lampang	18 15	99 30	243
330	Phrae	18 10	100 08	157
331	Nan	18 47	100 47	201
351	Uttaradit	17 37	100 08	63
353	Loei	17 32	101 30	211
354	Udon Thani	17 36	102 46	178
356	Sakon Nakhon	17 10	104 09	160
357	Nakhon Phanom	17 30	104 20	140
375	Mae Sot	16 40	98 33	210
376	Tak	16 51	99 07	115
378	Phitsanulok	16 50	100 16	50
379	Phetchabun	16 25	101 08	114
381	Khon Kaen	16 20	102 51	157
383	Mukdahan	16 33	104 44	138
400	Nakhon Sawan	15 48	100 10	28
403	Chaiyaphum	15 45	102 02	---
405	Roi Et	16 03	103 41	140
407	Ubon Ratchathani	15 15	104 53	123
425	Suphan Buri	14 30	100 10	7
426	Lop Buri	14 48	100 37	13
430	Prachin Buri	14 10	101 10	7
431	Nakhon Ratchasima	14 58	102 07	181
432	Surin	14 53	103 29	145
450	Kanchanaburi	14 01	99 32	28
455	Bangkok	13 44	100 30	12
456	Don Muang	13 55	100 36	12
459	Chon Buri	13 22	100 59	6
462	Aranyaprathet	13 42	102 35	44
475	Hua Hin	12 34	99 48	3
477	Sattahip	12 39	100 53	55
480	Chanthaburi	12 37	102 07	5

* Reference 3

TABLE II (Cont'd)

STATION INDEX, THAILAND

Index No.	Station	Lat. (N)	Long. (E)	Elevation (m)
500	Prachuap Khiri Khan	11° 48'	99° 49'	5
501	Khlong Yai	11 47	102 53	4
517	Chumphon	10 27	99 15	3
532	Ranong	09 58	98 38	35
551	Surat Thani (Ban Don)	09 08	99 18	3
552	Nakhon Si Thammarat	08 25	99 58	5
564	Phuket	07 58	98 24	3
567	Trang	07 30	99 40	12
568	Songkhla	07 11	100 37	4
583	Narathiwat	06 26	101 50	4

TABLE III

ANNUAL RAINFALL (MM) THAILAND, 1911-1960
(45 stations)

STA #**	300	303	325	327	328	330	331	351	353
Year									
1911	1151.5	1257.0		1305.6	984.2		1514.5		766.9
12	1316.3	1321.2		1245.8	987.6	1055.3	1692.8		1052.0
13	1103.8	1843.8		889.6	834.5	986.8	1300.2		1017.5
14	1047.9	1306.7		1070.2	1020.3	808.5	1857.3		1364.4
15	1197.1	1382.0		864.9	1028.8	1175.4	1997.3	1258.5	1291.4
16	1344.1	1615.5		1425.5	1243.1	1252.9	1828.4	2303.4	1376.6
17	1179.7	1579.6		1186.8	999.6	1344.9	795.0	1509.2	1354.2
18	1363.5	1638.0		1394.7	905.4	1272.5	1186.9	1837.3	1083.4
19	1314.8	1395.8		1165.5	878.7	910.5		1137.5	876.2
20	1074.7	1208.3		893.7	920.6	1174.7	1117.0	1309.2	1053.2
21	1285.1	1596.0		1254.9	1108.1	1205.8	1169.9	1692.6	1152.2
22	1117.9	1120.2		1256.3	1033.0	947.8	1016.7	1379.9	918.2
23	1171.7	1751.7		1281.7	950.7	1171.1	1186.1	1548.8	769.7
24	883.7	1260.1		1218.6	890.9	1179.0	902.6	1349.7	934.5
25	894.7	1329.3		1162.5	1016.3	1098.9	1246.1	1251.7	594.9
26	1136.9	1335.2		1075.9	772.6	1365.6	1173.2	1423.2	1085.4
27	1133.6	1703.1		1409.9	1384.6	1459.5	1588.2	1624.9	1134.3
28	1127.8	1509.2		1071.4	1029.9	1223.9	1151.4	1036.0	914.7
29	1311.2	1498.8		1209.7	849.3	1430.5	1287.7	1445.5	867.5
30	1058.3	1459.3		1134.9	1269.1	1568.2	1020.0	1203.4	862.5
31	975.6	1128.2		500.5	924.5	1100.5	1012.6	1456.7	620.6
32	917.9	1782.1	1012.9	1129.3	843.5	1019.4	955.9	1183.3	927.3
33	1267.0	1905.1	1223.4	1198.0	917.8	1445.2	1162.4	1973.3	875.1
34	1613.0	1820.6	868.9	1189.1	1202.7	1746.2	1488.0	1488.8	882.0
35	1406.6	1905.0	785.9	1254.6	1120.6	1208.3	1151.1	1932.8	1256.1
36	1055.5	1283.6	1061.9	913.9	938.4	902.2	1124.6	1236.1	518.4
37	1728.9	1374.8	2981.4*	1375.3	1110.1	1086.9	1397.5	1580.1	783.1
38	1400.6	1820.7	1637.6	1364.4	1173.7	1456.2	1551.1	1789.6	625.0
39	1348.9	1810.0	1842.6	1210.3	1100.9	1569.5	1283.3	1390.7	551.5
40	1367.6	1635.9		1073.0	777.3	1310.0	710.7	882.7	997.5
41	1221.8	2302.9	1067.4	970.5	922.2	1494.7	997.6	1769.7	1168.0
42	1578.4	2192.8	1254.5	1752.4	1377.1	1588.4	1249.7	2143.9	3367.0*
43	1404.2	2162.7	1106.4	1147.6		1126.0	1092.9	1360.0	2185.0
44		1510.8	1514.4		1190.5		758.8	1611.1	1463.1
45					1307.1			1457.3	1055.0
46				938.0	990.0		978.7	1295.0	457.9
47				1414.8	1107.0		920.9	1769.9	1681.0
48		1530.4	1388.4	1543.7	1112.8	1357.0	1256.4	1586.7	1711.3
49		1684.3	1027.6	1389.8		1296.0	1441.5	1476.6	1689.4
50	1487.2	1554.0	1314.5	1618.4		1534.7	1058.8	1812.9	1092.0
51	1272.8	2207.6		1473.3	919.3	1039.1	1606.5	1742.8	1411.9
52	1122.2	1681.9	1081.7	1364.0			1461.4	1247.8	1239.3
53	1383.7	1917.0		2032.5		1217.6	1329.1	1618.5	
54	999.6	1662.9	889.4	1276.5	1039.3	1093.0	1078.3	1374.8	
55	1268.0	1978.8	1046.2	1258.1	1143.1	944.5	1395.2	1363.9	1035.8
56	1366.1	2020.0	1290.1	1324.3	1072.6	1245.7	1288.7	1550.2	1449.6
57		1762.9	1081.7	1151.1	789.8	871.9	1311.6	1246.5	1182.0
58	1110.6	1668.9	1078.1	1129.9	905.5	850.8	961.8	1334.9	1045.5
59	1636.3	1764.5	1124.9	957.7	1247.2	1044.1	1294.0	1150.3	1119.6
60	1160.5	1701.0	1561.4	1339.1	1183.3	917.8	1285.7	1381.8	1116.6

* These years included in Table IVc, but deleted for IVb
** See Table II for name of station

TABLE III (Cont'd)

ANNUAL RAINFALL (MM) THAILAND, 1911-1960

STA #	354	356	357	375	376	378	379	381	383
Year									
1911	1417.6				1099.3	1208.6	1175.7	4001.9*	
12	1109.9	1501.3			1130.1	1428.8	1022.1		
13	1742.3	1228.6	1697.6		1032.4	1303.4	1453.0	1363.2	
14	1635.1	937.3	1947.7		1182.4	1737.0	1348.8	795.7	
15	1170.2	1261.7	1991.9		1174.2	1486.3	1056.5	1550.4	
16	1285.9	1038.1	2125.0		909.7	1923.4	1267.0	1080.6	
17	1093.5	1165.4	1831.2		1121.1	1747.3	1219.2	1316.7	
18	1634.8	1126.3	2391.9		757.4	1884.0	1024.3	1257.7	
19	1198.3	1078.1	2589.6		615.4	1244.6	1169.0	988.3	
20	1209.9	1715.2	2069.6		874.6	1211.5	1131.5	1056.1	
21	1004.2	1224.9	1816.4		618.1	2081.5	1414.5	1143.8	
22	1062.4	1584.6	1690.4		1342.1	1911.0	1399.1	901.0	
23	1629.1	1320.0	2760.6		784.4	1686.6	1186.6	1052.8	
24	1147.0	1453.2	2541.6		1076.6	1709.0	1662.5	1367.9	
25	929.4	1193.4	1557.8		788.7	1581.9	968.9	1067.8	
26	1320.2	973.4	1878.7		1359.5	1261.4	1388.0	1066.2	
27	1090.1	1310.6	2965.0		1099.0	1357.9	1462.0	1329.1	
28	1630.6	1389.1	2630.6		764.7	1323.1	1310.2	1407.7	
29	1318.8	1473.9	2285.7		473.8	1368.0	1304.1	997.9	
30	1016.5	1376.1	1997.4		572.1	1115.5	1209.6	890.5	
31	1034.5		2131.1		894.6	1124.5	1010.0	1090.8	
32	1011.0	1328.2	2025.2		838.3	1017.4	1447.2	1327.7	
33	1362.3	1839.4	2293.5		1043.0	1229.2	1169.4	856.5	
34	1456.6	2905.9	2516.9		990.0	1267.1	1264.5	1311.3	1580.9
35	1413.2		1972.2		939.5	1447.1	1570.9	1570.6	965.1
36	1218.8		1752.6		897.5	1244.3	1017.1	1239.5	1141.6
37	1394.3		2292.0		1602.8	1610.9	1241.5	1258.6	1499.0
38		4223.3*	1937.3		1107.6	1664.0	1770.8	1116.2	987.0
39	1372.6		1961.0		1151.1	1498.6	1441.6	369.0	1173.4
40	1259.8		2776.0		871.6	1319.0	1831.1	855.7	
41	1491.2	1847.5	2618.9		861.1	1266.2	612.2	761.0	1023.4
42	1898.5	1375.2	1835.6		1038.0	2253.1	1944.9	1525.5	1096.8
43	1262.9	1494.0	1979.1		908.3	1328.1	1476.5		1354.0
44	1215.1	1533.9			1109.9		821.8		
45	1459.1	1464.8			821.8	779.7	1517.1	1362.0	1212.7
46	1271.2	1540.0	2053.9		673.0	894.3	1241.3		
47	1384.3	1290.4	2146.2		1125.8	1063.1	1103.4	1175.6	
48	1502.8		2444.4	1175.1	893.1	1713.8	1155.1	1216.9	
49	1681.0	1791.6	2215.9	1284.2	1109.1	1747.7	1174.3	1672.3	1710.7
50	1730.0	1533.4	2427.8	1701.5	686.0	1785.8	1389.2	1343.3	1191.2
51	1788.1	1364.9	1969.5	1808.5	542.5	1294.4	1155.1	1597.3	1516.0
52	1689.3	1347.9	2420.8	1342.7		1046.4	1510.5	1162.4	1756.8
53	1597.1	1709.8	2237.6	2123.6	1023.5	1410.7	1416.3	1424.3	1034.6
54	1235.6	1464.8	2408.7	1040.5	1063.3	1307.7	1365.6	1286.4	1490.7
55	1144.5	991.3	1595.3	1388.7	896.9	1479.4	919.2	1085.4	1460.7
56	1365.7	1551.2	2093.4	1106.7	870.0	1630.0	1100.5	992.3	1715.5
57	1313.1	1108.4	2212.6	1348.8	932.0	1025.3	1109.5	1076.7	1437.8
58	1395.7	1240.1	2189.0	1094.4	954.8	1375.2	1194.5	1118.7	1100.7
59	1523.4	1132.3	1780.9	1459.4	1363.2	1270.0	1352.0	1168.3	1355.0
60	1608.3	1679.3	2501.6	1311.7	1141.4	1302.1	806.0	945.0	1618.1

* These years included in Table IVc, but deleted for IVb

TABLE III (Cont'd)

ANNUAL RAINFALL (MM) THAILAND, 1911-1960

STA #	400	403	405	407	425	426	430	431	432
Year									
1911	819.0	775.6	1300.4	1164.1	1078.2	1043.8	1718.5		1121.4
12	1103.2	1176.6	1246.2	1302.8	1256.9	1352.0	1957.3	1117.3	1229.5
13	944.3	531.5	1269.9	1490.8	1248.1	1016.5	2107.4	869.5	1265.6
14	857.2	780.1	1178.4	1582.7	1268.7	1337.8	1982.3	984.5	1074.3
15	1069.7	1054.6	1241.8	1690.3	1344.6	1269.0	1574.5	1263.7	1415.5
16	1153.7	1237.5	993.5	668.3	1442.5	1529.9	1524.6	1258.4	1398.9
17	1174.9	1226.5	1494.7	1740.5	1141.0	1288.8	2270.0	1169.4	1705.3
18	735.2	960.7	1355.9	1461.8	750.8	1128.8	2563.7	749.3	1228.9
19	1020.7	563.9	1259.0	1294.4	1247.1	890.8	1888.4	921.2	1074.4
20	691.5	935.6	1801.2	1657.9	510.8	1222.6	1659.7	730.7	1186.8
21	1090.4	990.6	1347.2	1257.9	1095.3	1447.2	2219.1	955.6	1055.6
22	1054.5	934.9	828.5	1043.5	1247.8	1080.6	1767.6	851.2	1221.5
23	1145.5	1039.7	1291.1	1698.2	1295.0	1445.5	3138.6	1636.3	1856.1
24	1104.6	1016.9	1307.5	1168.2	1423.1	1280.9	1869.7	1362.6	1496.8
25	1108.3		1394.3	1906.1	1364.6	1284.7	1575.9	1144.8	1458.9
26	1010.2	1145.0	1158.2	1683.0	1902.1	1435.4	1854.7	1773.3	1928.8
27	914.6	951.2	1502.9	1303.7	1279.9	1416.9	1808.0	964.4	940.9
28	721.8	1167.1	1398.6	1035.7	1144.7	1007.1	1982.6	1170.7	1348.8
29	1299.1	891.7	866.1	1372.3	650.3	1027.1	1886.1	1173.6	1229.2
30	1231.0	1172.8	949.4	1626.7	928.9	1430.7	4156.4	1362.6	1374.8
31	1376.7	1240.6	1554.2	1476.3	916.2	1009.5	2387.4	974.3	1217.8
32	1166.1	1054.5	1298.0	1715.0	1299.1	1245.6	2714.6	1019.6	1156.2
33	1230.2	1028.1	1228.9	1516.2	1432.9	1089.7	2328.0	1155.3	1185.5
34	1218.8	1437.5	1862.0	1682.7	877.9	995.1	2846.7	1199.0	1559.9
35	1295.5	1123.4	1660.8	1868.3	1520.5	1288.2	3285.5	1421.4	1634.4
36	1212.7	760.4	1433.2	1080.2	1053.4	917.6	1689.2	1006.4	1357.5
37	1250.9	1110.1	1360.4	1070.9	1101.1	304.6	2358.2	968.0	1096.0
38	1161.8	1283.0	1540.5	1221.3	1749.0	1164.4	2138.9	1345.6	1598.0
39		1107.8	1532.8	1536.2	1204.8	1066.3	1806.6	953.5	1120.2
40		1051.4	1086.1	1301.4	1233.3	1085.1	1544.5	874.9	1262.7
41	1136.6	1159.6	1655.0		637.7	1126.8	1735.5	950.5	1547.0
42	1319.2	1574.8	1418.8	1582.5	1599.9	1584.3	2193.3	1412.5	2058.1
43		1013.4	759.9	1858.9	1383.4	1049.2	1685.7	1085.2	975.1
44		964.1	1040.8	1406.0	1371.4	1272.5	1698.1	1460.8	996.6
45			1392.8	1865.9	1266.0	1180.4	2809.7		
46		550.5	1459.8	1528.3	976.1	1593.3	2321.5	829.1	1470.0
47			1606.1	1393.3	1311.8	1328.5	1563.6	1147.3	1263.7
48	1157.8		1785.4	1738.1	1245.8	1508.8	2437.9	1095.4	1584.5
49	1236.6	1053.1	1643.1	1777.9	1208.1	1573.1		1363.3	1334.5
50	1140.4	839.4	1716.5	1819.4	1248.9	1156.0	1911.8	1142.3	1515.1
51	1448.0	1071.4	1497.8	1700.4	1245.8	1367.9	1811.3	1360.0	1484.2
52	1346.9	873.5	1350.5	1696.6	1430.7	1246.3	1892.9	1193.4	1288.7
53	1463.6	831.3	1243.7	1210.7	1502.5	1511.6	1862.1	1323.3	1341.8
54	953.9	877.6	1249.4	1338.0	1107.7	1201.1	1852.7	1191.5	1075.4
55	1314.8	916.9	1116.9	992.9	1335.8	1351.7	2197.1	1312.3	1347.0
56	1358.5	1007.7	1501.2	1916.4	1385.3	1435.5	2248.1	1260.7	1185.2
57	1132.2	1350.8	1194.0	1491.0	1590.1	1937.2	2224.6	1098.9	1203.6
58	891.4	1204.1	1237.9	1273.3	1773.6	1244.7	1993.1	1244.9	1312.5
59	1119.7	1406.6	1376.5	2304.7	1330.3	1310.4	1847.3	1399.7	1235.5
60	888.7	865.9	1648.9	1696.4	1346.7	908.3	1579.3	1005.1	1297.7

TABLE 111 (Cont'd)

ANNUAL RAINFALL (MM) THAILAND, 1911-1960

STA #	450	455	456	459	462	475	477	480	500
Year									
1911	1237.0	1444.9						2235.3	
12	1025.9	1071.0						3178.9	
13	1148.7	1119.3						2549.8	
14	904.9	1384.7						2353.6	
15	1236.3	1234.1						2530.5	
16	1319.6	1365.8						3110.5	
17	1238.1	1491.9						2873.0	
18	837.1	1065.0						2041.4	
19	1188.3	1266.3						2492.4	
20	1138.0	890.8						1929.4	
21	898.9	1319.2						2538.8	
22	645.5	1191.4						2057.7	
23	1000.5	1423.5						2536.9	
24	1009.6	1416.4						2888.9	
25	605.5	1277.6						1908.6	
26	803.0	1546.2						2305.9	
27	700.6	1433.6						2080.7	
28	614.3	1552.8						2437.0	
29	829.1	1285.2						2420.0	
30	727.9	1205.1						1769.9	
31	849.6	1772.8		1318.1				2038.4	
32	1038.8	1707.9		1831.2	1382.9			2227.1	969.7
33	959.9	1243.5		1587.0	1167.4			3132.9	926.9
34	705.6	1142.5		853.0	1359.8			2691.2	873.2
35	1137.4	2072.1		1637.4	1986.0			3387.3	1584.2
36		1361.2		874.0	907.8			2509.8	992.9
37	756.0	1207.7		914.5	1182.9			3516.9	1231.6
38	1787.7	1507.5	1530.2	1722.0	1610.9		1373.8	3627.5	873.5
39		1254.3	1295.2	964.5	1646.8		854.1	2461.2	1377.9
40	601.4	1019.7	1057.1	771.7	1060.0		1025.5	2640.5	1077.7
41	473.3	1309.3	1573.4	935.2	1571.0		1211.7	2807.7	
42	1030.0	1701.0	1603.7	1266.8	1492.8		2006.3	3043.1	1420.4
43	1140.5	1532.7	1725.8	1009.9	1654.4	1173.3	1312.5	2907.0	1220.9
44		1735.2	1558.0	1199.2		893.7	1236.2	2612.5	1805.1
45	890.7	1373.4	1747.0	1619.7	1428.5		1115.7	4158.2	
46	536.7	1261.9	1377.3	1217.3	1675.9	627.1	984.0	3441.8	
47	896.3	1486.0	1509.0	1291.3	1569.5	1792.0	1498.1	2958.1	
48	994.0	1614.4	1414.4	1340.5	1513.0	1051.5	1182.3	3554.0	1094.1
49	886.9	1697.9	1785.3	1614.2	1310.8	830.9	1343.1	3215.6	1049.7
50	1168.8	[illegible]	1366.1	1226.7	1848.7		1460.9	3160.2	1362.5
51	1090.5	1647.0	1807.4	1668.4	1718.4	868.8	1238.2	2902.5	1239.6
52	1169.1	1516.1	1827.1	1513.6	1884.1	1170.7	1506.7	3417.2	1342.6
53	1351.8	1584.0	1581.4	1681.4	1824.3	1491.9	1149.3	3638.0	1523.6
54	928.5	1495.0	1290.7	1412.2	1207.0	894.6	1291.3	3546.0	953.1
55	1537.7	1513.8	1361.8	1698.8	1598.8	1229.4	1072.0	3566.3	1479.8
56	1373.9	1372.2	1953.9	1462.5	1824.6	1189.2	1092.9	2990.2	991.0
57	1406.1	1956.7	2050.8	1588.3	1642.2	934.1	1590.1	3448.4	663.5
58	782.2	1297.9	1170.7	1286.0	1783.6	892.1	1023.6	2783.8	927.3
59	1515.4	1275.7	1552.1	1154.3		953.6	1258.8	2978.6	1150.9
60	877.6	1646.3	1438.8	1227.6	1712.1	880.8	1248.7	3791.7	907.3

TABLE III (Cont'd)

ANNUAL RAINFALL (MM) THAILAND, 1911-1960

STA #	501	517	532	551	552	564	567	568	583
Year									
1911		2686.3	3442.1		3876.5	1828.9	1180.3	2303.5	
12		2081.3	3342.5		2771.2	2477.9	2505.2	1470.4	
13		2641.2	3848.7		3315.9	2508.0	2487.0	1731.4	
14		2815.4	3553.8	1389.1	2780.0	1365.0	2977.8	2094.1	1713.8
15		1686.2	3789.8	1924.5	3628.8	2616.4	2674.2	2485.1	2698.7
16		1923.3	3412.6	1760.6	4415.6	2140.1	3230.1	2022.0	3049.3
17		1306.0	4010.8	1805.6	2547.6	2587.1	2442.2	1898.1	2877.3
18		1951.2	3503.8	1396.7	2785.6	2282.3	2879.9	1731.2	2826.5
19		2011.8	4033.9	2014.8	2228.6	2686.3	2729.9	1781.3	2815.9
20		2965.6	4419.4	2082.4	2009.1	2178.9	2051.0	2244.5	3407.9
21		1754.8	4522.1	1725.4	1860.0	2753.6	2744.7	1657.8	2239.6
22		2416.9	4325.3	2747.6	2513.7	2257.0	2847.2	2561.8	3958.1
23		3435.1	4068.3	1169.5	1982.4	2873.5	1166.3	1348.4	2820.3
24		1951.8	3440.1	1900.6	1741.5	2273.9	2643.4	1588.9	
25		2593.4	4491.4	2367.6	2119.4	2454.3	1959.2	1587.2	2361.3
26		1647.3	5267.7	2465.4	1992.0	2314.2	2301.7	2131.8	
27		1582.6	6073.9	2096.1	2044.3	2577.7	2808.8	2067.1	2352.8
28		1798.8	5151.5	2189.8	3148.4	1799.6	1990.6	2649.9	2656.4
29		2420.6	5208.4	1839.4	1769.6	2009.9	1846.3	1179.6	1652.1
30		2218.4	4103.3	2189.7	1559.2	1389.4	2109.1	2111.2	3015.2
31		1860.9	6810.1	1699.2	2115.9	2424.0	2649.7	2031.1	2559.5
32	2107.0		5571.1	1814.4	2734.0	2683.1	2510.5	2620.2	2482.4
33		1574.2	5186.5	1587.5	2975.7	2228.9	2356.3	2578.0	2764.9
34	1983.7	1757.0	6613.3	1870.3	2253.4	2427.9	2152.3	2935.4	2999.1
35	2081.9	2256.6	6049.4	2039.1	2863.9	2605.8	2480.6	2477.5	3388.6
36	3535.1	1785.4	5998.4	1602.4	2753.5	2140.7	1862.7	1814.9	3017.2
37	3198.3	2628.4	6213.7	1730.9	2877.3	2071 3	2619.4	1857.7	2937.8
38	4127.5	1841.1	6765.9	2050.5	2908.4	2061.6	2573.7	2647.1	2510.7
39	5028.1	1587.4	6187.3	2096.3	2671.4	2639.9	2238.9	2369.4	1893.3
40		2511.5	5043.0	1210.1		2279.1	1642.6	1824.1	
41	5213.9	2630.1	5873.3		4227.9	2333.5	1698.6		
42	4542.7	1956.2	4673.7	2151.2	3075.8	2706.6	2364.2	2901.8	
43	5756.3	1735.7	6368.9	2313.6	2678.4	2362.4	2315.2	1744.6	
44	4762.4	2201.9		2583.5	2721.2	2013.9	1803.7	2196.7	2303.3
45				2198.7	3402.9				3449.0
46		2377.3		2084.6	3290.6	2087.4	2269.3	3154.3	
47		2439.8		1910.1			1884.6		3356.7
48		1728.0	4051.7	1488.3		2305.8		2178.1	2442.5
49		1788.9	5418.1	1449.6	2274.0	2834.4		2078.9	2490.4
50	4607.7	1704.2	4141.4	2141.1		2514.1	3104.4	2159.9	2133.1
51	4889.7	1938.1	3466.2	2180.9		2590.3	3222.6	2277.7	
52	5220.8	2097.7	4960.9	1894.5		2482.6	2695.1	2021.1	2149.2
53	4423.1	2329.3	4321.8	2062.5	3209.0	2537.8	2794.5	2382.7	2937.6
54	5522.3	2037.3	4892.4	1331.5	1998.0	2783.1	2774.6	2026.5	2673.9
55	4244.1	2387.9	3808.5	1871.2	2204.6	1980.9	1951.0	2243.7	2587.4
56	5448.9	2296.8	4236.7	2200.3	2801.6	2580.4	2300.8	2328.7	2642.0
57	4601.9	1320.5	4243.8	922.9	1942.7	2201.1	2800.1	1551.3	2103.5
58	4072.0	1574.0	4399.5	2030.5	2214.3	1921.8	2278.9	1603.4	2428.8
59	5178.6	2110.3	4531.7	1573.3	2495.1	2347.2	2120.6	2216.9	3310.6
60	5622.7	1741.2	4584.5	1563.3	2259.7	2478.9	2142.0	1831.0	2579.1

TABLE IVa

STATISTICAL ANALYSIS* OF ANNUAL RAINFALL: 3 stations, Canal Zone (1911-1960)

Station	No. Years Record	Mean	Mean Dev	Std Dev	Coeff Var	Skewness	Kurtosis
		(mm)	(mm)	(mm)	(%)		
Cristobal	50	3315.5	395.5	485.2	14.6	0.305	2.32
Balboa Heights	50	1768.3	193.4	234.9	13.2	0.036	2.17
Gatun	50	3103.0	416.8	491.7	15.8	-0.070	2.16

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* Equations for Table IV:

$$\text{Mean} = \bar{X} = \frac{\Sigma X}{N} \qquad (1)$$

$$\text{Mean Dev} = D = \frac{\Sigma /X - \bar{X}/}{N} = \frac{\Sigma /x/}{N} \qquad (2)$$

$$\text{Std Dev} = S = \sqrt{\frac{\Sigma x^2}{N-1}} \qquad (3)$$

$$\text{Coeff Var} = C = \frac{100\ S}{\bar{X}} \qquad (4)$$

$$\text{Skewness} = S = \frac{\Sigma x^3}{N\ S^3} \qquad (5)$$

$$\text{Kurtosis} = K = \frac{\Sigma x^4}{N\ S^4} \qquad (6)$$

where X = individual annual rainfall

N = number of years of record

TABLE IVb

STATISTICAL ANALYSIS OF ANNUAL RAINFALL: 45 stations, Thailand (1911-1960)

Sta** No.	Rec-ord (yr)	Mean Amt (mm)	Mean Dev (mm)	Std Dev (mm)	Coeft Var (%)	Skew-ness	Kur-tosis
300	43	1239.7	159.6	197.3	15.9	0.37	2.72
303	47	1635.7	231.1	290.2	17.7	0.28	2.45
325*	22	1193.6	207.7	263.0	22.0	0.75	2.83
327	48	1225.2	174.0	246.2	20.1	0.30	5.06
328	45	1033.9	126.6	156.1	15.1	0.38	2.37
330	44	1206.8	183.9	228.0	18.9	0.27	2.24
331	48	1242.4	213.9	279.4	22.5	0.55	3.12
351	46	1489.6	221.6	285.0	19.1	0.61	3.33
353*	47	1076.8	251.8	341.6	31.7	0.70	3.94
354	49	1361.8	194.3	237.1	17.4	0.23	2.13
356*	41	1411.8	227.8	335.4	23.8	2.04	10.18
357	46	2164.3	272.6	332.2	15.4	0.30	2.35
375	13	1398.9	230.4	312.4	22.3	0.92	2.81
376	49	961.7	178.2	226.6	23.6	0.17	3.17
378	49	1428.9	247.0	308.5	21.6	0.43	2.84
379	50	1272.0	198.0	256.6	20.2	0.14	3.39
381*	45	1167.6	194.9	251.6	21.5	-0.43	3.71
383	22	1337.3	222.5	255.5	19.1	0.10	1.54
400	43	1117.9	146.2	189.7	17.0	-0.43	2.58
403	46	1028.5	164.9	219.0	21.3	-0.07	3.21
405	50	1352.7	191.0	247.4	18.3	-0.21	2.79
407	49	1494.0	246.5	305.9	20.5	-0.15	3.05
425	50	1246.1	192.6	274.1	22.0	-0.39	3.68
426	50	1239.8	184.2	250.2	20.2	-0.57	5.76
430	49	2091.2	372.3	509.1	24.3	1.77	6.97
431	48	1151.1	174.5	221.3	19.2	0.36	2.96
432	49	1333.0	183.3	239.9	18.0	0.91	3.72
450	47	999.9	225.2	283.2	28.3	0.42	2.87
455	50	1418.5	186.8	235.9	16.6	0.34	3.11
456	23	1546.8	191.6	246.5	15.9	0.11	2.33
459	30	1329.6	250.9	301.2	22.7	-0.20	1.79
462	27	1539.4	216.3	269.7	17.5	-0.53	2.43
475	16	1054.6	214.9	284.2	26.9	1.03	3.59
477	23	1266.8	177.6	252.0	19.9	1.20	5.10
480	50	2827.9	469.5	565.1	20.0	0.14	2.16
500	25	1161.6	224.9	272.1	23.4	0.44	2.41
501	22	4371.3	874.6	1141.4	26.1	-0.91	2.67
517	48	2085.1	361.4	444.8	21.3	0.64	3.15
532	46	4748.3	845.1	1005.9	21.2	0.49	2.07
551	46	1885.2	295.1	377.0	20.0	-0.26	2.90
552	44	2637.2	511.7	651.0	24.7	0.72	3.16
564	48	2333.3	258.4	333.4	14.3	-0.86	3.73
567	47	2365.6	373.9	470.4	19.9	-0.45	2.95
568	47	2100.0	334.3	425.8	20.3	0.21	2.69
583	39	2681.7	377.5	490.5	18.3	0.17	..98

* Extreme year eliminated: see Table IVc for original statistics

** See Table II for Station Index

TABLE IVc

4 STATIONS, THAILAND, INCLUDING EXTREME YEAR (ORIGINAL DATA)*

Sta No.	Record (yrs)	Mean (mm)	Mean Dev (mm)	Std Dev (mm)	Coeff Var (%)	Skew-ness	Kur-tosis	Extreme Year	Standard Error
325	23	1271.4	292.1	452.8	35.6	2.32	9.11	1937	6.5
353	48	1124.5	301.5	472.7	42.0	2.33	11.53	1942	4.8
356	42	1478.8	298.5	545.8	36.9	3.36	16.44	1938	5.1
381	46	1229.2	257.8	486.3	39.6	3.87	23.28	1911	5.8

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* Explanation and comment on this table:

Table IVc contains the original statistical analysis of the four stations indicated. Since the values for the coefficient of variation, skewness and kurtosis were relatively high compared to the rest of the stations in Thailand (Table IVb) the data for these four stations were re-examined and the extreme year determined in each case. These years were considered suspect because the odds against their occurrence were so great. Table IVc also includes the dates of these years and the standard errors (Z's) represented by the respective amounts of rain (for Z = 5, the odds against occurrence are 1,744,000 to 1).

$$Z = \frac{X - \bar{X}}{S}$$

where X = individual annual rainfall
$\bar{X}$ = mean annual rainfall
S = standard deviation

Consequently, the rainfall for the extreme year was eliminated from the respective lists of annual rainfall (Table III), and the remaining data re-analyzed, with the results as shown in Table IVb. The differences in the two sets of values are considerable. For instance, kurtosis for Knon Kaen (station #381) was reduced from 23.3 in Table IVc to 3.7 in Table IVb (normal kurtosis = 3.0).

The four extreme years are to be checked further. Addition of monthly rainfalls in each case indicates no error in arithmetic. Moreover, at other stations in Thailand, as well as elsewhere, high annual rainfalls did occur in the years 1937, 1938, and 1942 (Table III). If the extreme observations were in fact valid, the importance of kurtosis and skewness in the detection of "singular" events is readily seen.

TABLE V

STATISTICAL SAMPLING OF ANNUAL RAINFALL FOR SIX STATIONS IN THAILAND

Sta No.	Date of Record	Mean Amt (mm)	Mean Dev (mm)	Std Dev (mm)	Coeff Var (%)	Skew-ness	Kur-tosis	Ninety Percent* Mean Range P_{05}	P_{95}
379	1911-1960	1272.0	198.0	256.6	20.17	0.14	3.39		
	1911-1940	1307.9	174.7	221.1	16.91	0.49	2.66	1241.5	1374.3
	1921-1950	1316.8	218.6	287.6	21.84	-0.05	3.08	1230.5	1403.2
	1931-1960	1271.0	234.1	300.8	23.67	0.14	2.81	1180.6	1361.3
	1951-1960	1192.9	174.9	223.0	18.69	-0.25	1.71	1076.9	1308.9
405	1911-1960	1352.7	191.0	247.4	18.29	-0.21	2.79		
	1911-1940	1324.7	179.5	242.3	18.29	0.03	2.88	1252.0	1397.5
	1921-1950	1369.3	218.6	282.9	20.66	-0.48	2.44	1284.3	1454.2
	1931-1960	1415.1	191.7	243.2	17.19	-0.45	2.97	1342.0	1488.1
	1951-1960	1341.7	133.3	165.6	12.34	0.43	1.79	1255.6	1427.8
425	1911-1960	1246.1	192.6	274.1	22.00	-0.39	3.68		
	1911-1940	1200.3	210.3	290.6	24.21	-0.10	3.44	1113.0	1287.6
	1921-1950	1232.3	199.5	278.0	22.56	0.00	3.25	1148.8	1315.8
	1931-1960	1289.5	182.0	248.0	19.23	-0.35	3.23	1215.1	1364.0
	1951-1960	1404.8	135.5	185.0	13.17	0.41	2.41	1308.6	1501.1
426	1911-1960	1239.8	184.2	250.2	20.18	-0.57	5.76		
	1911-1940	1170.1	181.6	240.8	20.58	-1.32	6.14	1097.7	1242.4
	1921-1950	1213.2	195.9	260.6	21.48	-1.11	5.60	1134.9	1291.5
	1931-1960	1235.1	202.5	288.6	23.36	-0.54	5.20	1148.5	1321.8
	1951-1960	1351.5	169.3	262.3	19.41	0.62	3.33	1215.0	1487.9
455	1911-1960	1418.5	186.8	235.9	16.63	0.34	3.11		
	1911-1940	1342.5	179.1	240.1	17.88	0.84	4.12	1270.4	1414.6
	1921-1950	1442.9	186.9	230.9	16.00	0.54	2.91	1373.6	1512.3
	1931-1960	1498.0	191.5	240.5	16.06	0.24	2.60	1425.8	1570.3
	1951-1960	1530.5	142.4	199.3	13.02	0.60	2.61	1426.8	1634.1
480	1911-1960	2827.9	469.5	565.1	19.98	0.14	2.16		
	1911-1940	2549.1	370.5	485.2	19.03	0.56	2.45	2403.3	2694.8
	1921-1950	2767.8	470.0	575.9	20.81	0.33	2.39	2594.9	2940.8
	1931-1960	3105.1	401.7	490.4	15.79	-0.14	2.39	2957.8	3252.4
	1951-1960	3306.3	314.0	356.9	10.80	-0.20	1.22	3120.6	3491.9

* P_{05} = 5th percentile of mean

P_{95} = 95th percentile of mean

TABLE VI

RUNOFF AT GATUN LAKE BASIN AND RAINFALL AT GATUN, CANAL ZONE (1957-1962)

Year	Total Runoff at Gatun Lake Basin (million m^3)	Annual Rainfall at Gatun (cm)	Percentile Rank of Rainfall
1960	7437	390	93
1961	5324	288	30
1959	5242	285	29
1962	5092	342	71
1958	4821	310	46
1957	4109	261	15
48-year mean	5897		

Area of Gatun Lake Basin: 3340 km^2

TABLE VII

RAINFALL, RUNOFF, AND GAGE HEIGHT AT UBON* ON THE MAE NAM MUN, THAILAND (1960-1965)

Year	Total Annual Runoff (million m^3)	Maximum Gage Ht. (m)	Date Oct	No. days Gage Ht. $\geq$ 10 m	No. days Gage Ht. $\geq$ 5 m	Period Gage at $\geq$ 4 m** Start – End	Annual Rainfall (cm)	Percentile Rank
1962	29,600	10.4	16	22	140	Jul 14 - Nov 30	204	96
1961	23,800	9.6	7, 9	0	72	Aug 22 - Nov 23	181	86
1964	22,100	9.7	6	0	71	Sep 19 - Dec 9	163	64
1960	20,300	8.4	28	0	88	Aug 20 - Nov 26	170	72
1963	18,100	6.6	8	0	97	Aug 9 - Dec 7	152	51
1965	12,000	4.8	4, 5	0	0	Jun 26 - Oct 15 (intermittent)	130	28
Avg. (1951-65)	19,300							

* Ubol
Station location: 15°13.3' N, 104°51.7' E
Drainage area: 104,000 km^2
Gage elevation: 105.07 m (above mean sea level)

**Roughly equivalent to a discharge rate of 1000 m^3/s

TABLE VIII

MONTHLY RAINFALL AS PERCENT OF AVERAGE ANNUAL RAINFALL PER QUINTILE RANGE: CRISTOBAL AND CHANTHABURI

Station	Quintile Range (%)	Average* Annual Rainfall (cm)	Percent of Average Annual Rainfall J	F	M	A	M	J	J	A	S	O	N	D
Cristobal	20	282	2.8	1.5	0.7	3.1	8.7	9.4	12.1	15.2	9.8	12.9	18.1	7.9
	20 to 40	317	2.3	1.1	0.9	1.8	8.2	8.6	10.5	11.6	11.9	11.8	18.9	12.6
	40 to 60	338	1.8	0.9	1.6	2.3	6.8	8.5	11.5	11.5	8.1	14.3	18.4	9.6
	60 to 80	362	2.5	1.5	1.5	2.8	10.3	6.5	11.9	10.9	8.8	12.7	19.9	9.2
	80	416	1.7	0.7	1.1	3.6	10.1	11.2	10.9	9.4	8.7	11.7	15.3	15.1
Chanthaburi	20	242	0.2	1.1	1.7	3.6	15.4	16.9	18.4	14.4	16.3	7.2	5.6	0.5
	20 to 40	284	1.1	0.6	2.1	3.9	11.9	14.2	17.6	17.9	18.5	9.6	1.8	0.3
	40 to 60	309	0.9	1.0	3.0	5.0	10.5	16.4	18.5	14.8	19.5	8.7	1.9	.03
	60 to 80	346	0.4	1.1	2.2	5.2	10.0	14.6	18.9	16.5	20.0	9.8	1.5	.1
	80	372	0.8	2.0	1.8	4.2	10.4	19.5	16.6	17.0	15.7	8.5	7.4	.7

*Rainfall averaged over successive sets of 6 years ordered by magnitude (1931-1960)